NOV 25 1930

Which Are The Industrial Instruments?

INSTRUMENTS

INDUSTRIAL — SCIENTIFIC

(Reg. U. S. Pat. Off.)

Devoted to Measurement and Control Problems

Vol. 3. No. 11 Pittsburgh, Pa. November, 1930

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Place initials of interested persons in your organization opposite title and call it to their attention.

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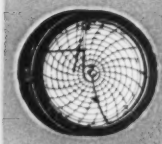

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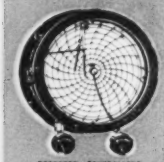

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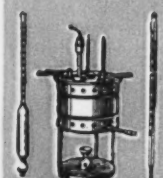
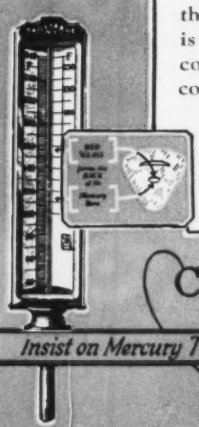
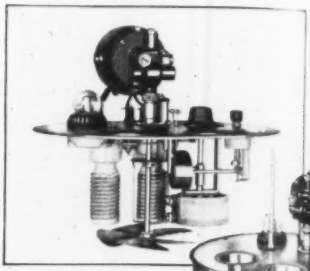


OIL TESTING INSTRUMENTS, THERMOMETERS, HYDROMETERS, ETC.





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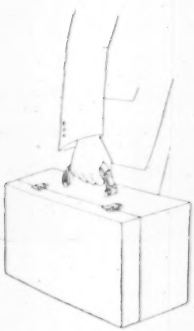
This new two-element OSCILLOGRAPH *is a simple, portable instrument*



THIS portable oscillograph is self-contained, and weighs only 30 lb., including the accessories in a built-in compartment.

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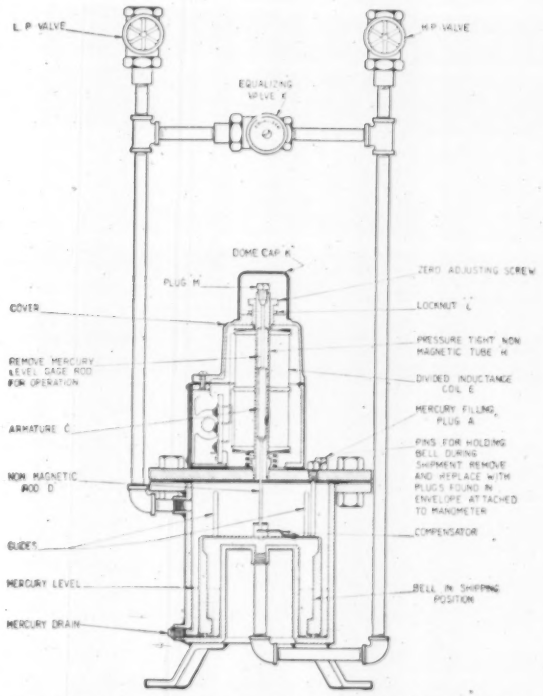

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Low Pressure Flow Meter Manometer

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on the Inductance Bridge Principle

MANUAL 6
AUTOMATIC 7

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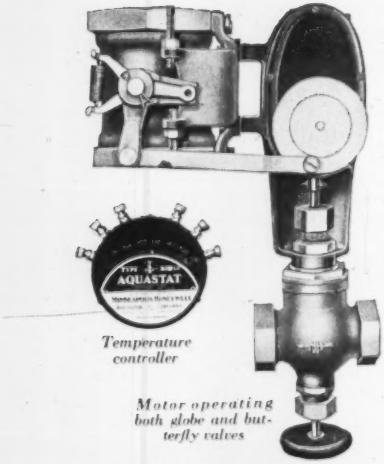
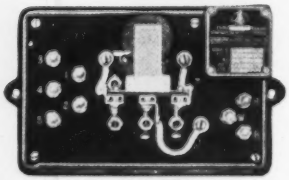


Temperature controller

Motor operating both globe and butterfly valves



Relay for the control of electric heaters, and motor valves of oil or gas fired furnaces

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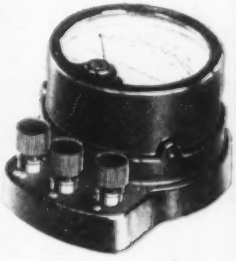
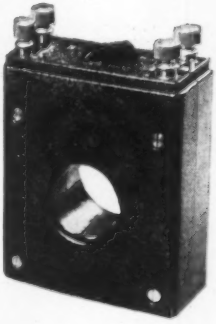


Model 528 Voltmeters are made in double and triple range combinations with high internal resistance. Self-contained for ranges up to 600 Volts.

Model 528 Ammeters and Milliammeters are made in single ranges. The Ammeters have ratings from 1 to 50 amperes and the Milliammeters from 15 to 500 Milliamperes.



Model 539 Current Transformer permits measurements from 0.2 to 200 amperes. It has four self-contained primary ranges—2, 5, 10, 20 amperes (selected by a self-contained fool-proof and positive switch) and three inserted primary ranges of 200, 100, and 50 amperes, (procured by passing the conductor 1, 2, and 4 times through the hole in the transformer). Secondary burden two Volt-amperes. Maximum working range of 750 Volts. Accuracy 1% on frequencies from 25 to 150 cycles. Size: 5½ x 4⅛ x 1⅞ inches. Weight: 2⅝ pounds.

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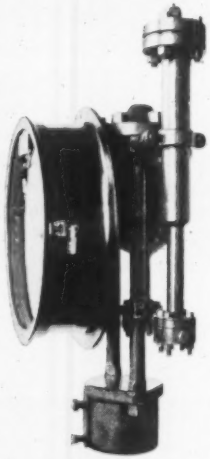

Foxboro High-Pressure Flow Meters for Working Pressures to 5000 pounds. Tested at 15,000 lbs. Hydraulic Pressure.

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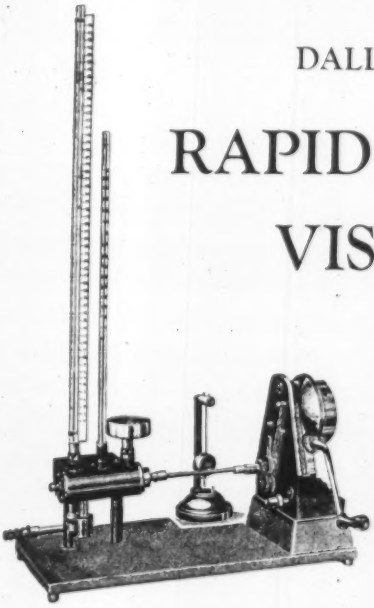

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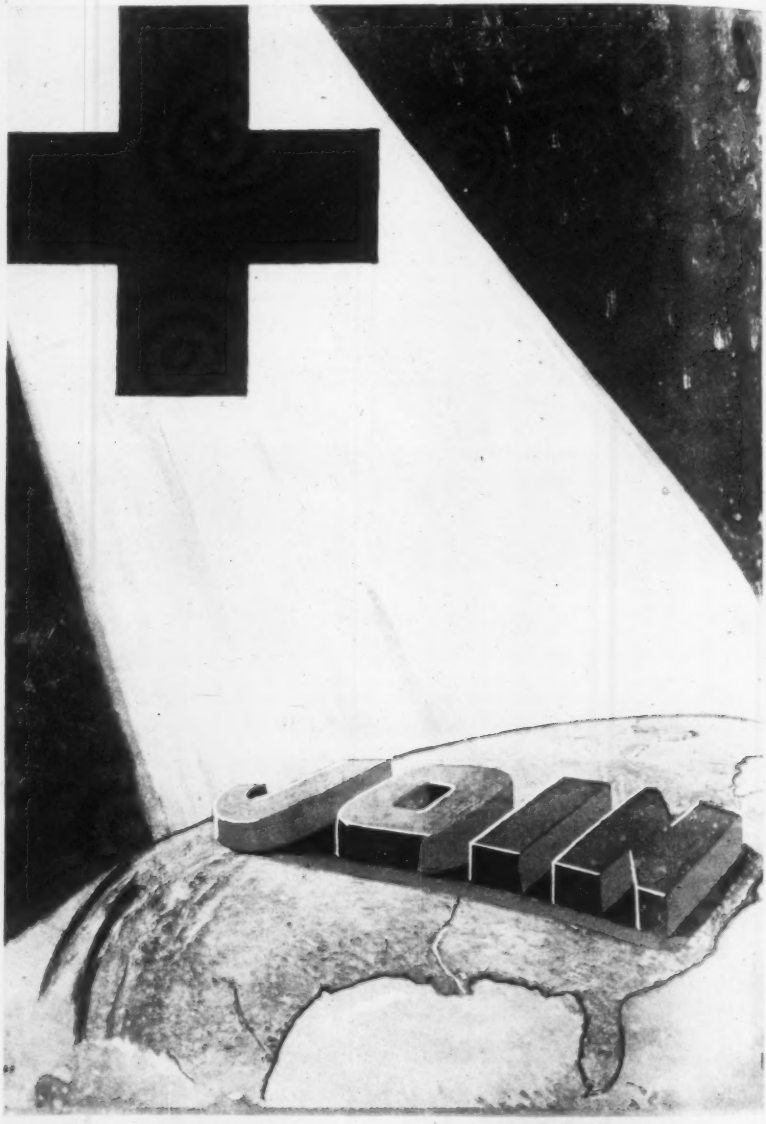
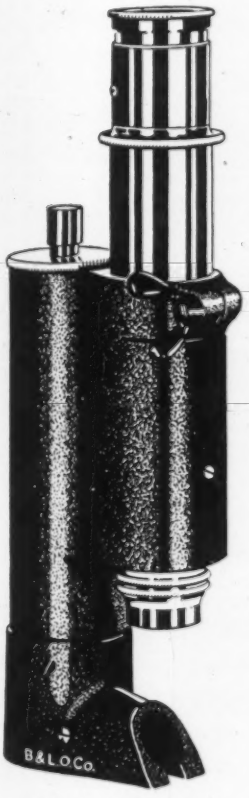


THE AMERICAN RED CROSS



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AND now Bausch & Lomb presents an instrument having many applications both in the machine shop and in the laboratory. The Shop Microscope is a small, portable microscope, carrying its own illumination. It contains a micrometer in the eyepiece wherewith exact measurements can be made to one thousandth of an inch and one-fifth of that interval easily estimated.

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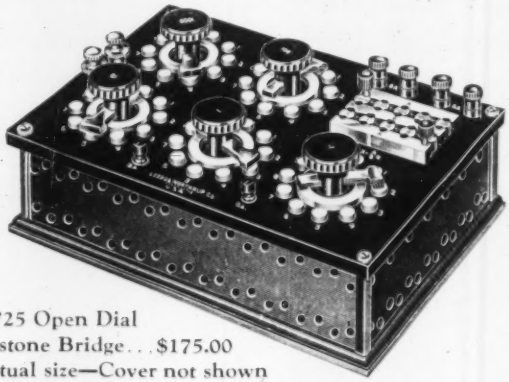

No. 4725 Open Dial
Wheatstone Bridge . . . $175.00
1/6 Actual size—Cover not shown

THE dial construction of this bridge allows very rapid operation and the limit of error of 0.05% is small enough for most work. Five decades are provided each having nine coils, except the 0.1 ohm decade, which has ten coils to permit interchecking the dials. Two ratio coils of each value are provided, and any coil can be connected in either arm of the bridge. When using a 1 to 1 ratio the equality of the ratio arms can be checked by reversing them, and when using an uneven ratio, duplicate coils serve as a check on each other. The coils are wound on metal spools soldered directly to rods integral with the exposed switch contacts, the contacts serving as heat radiators. The black metal case is perforated not only to assure good ventilation in air but to permit the box to be immersed in an oil bath. The coils dissipate 0.5 watt each. The metal parts are heavily nickel plated and the top plate is polished hard rubber. The instrument has a polished mahogany cover.

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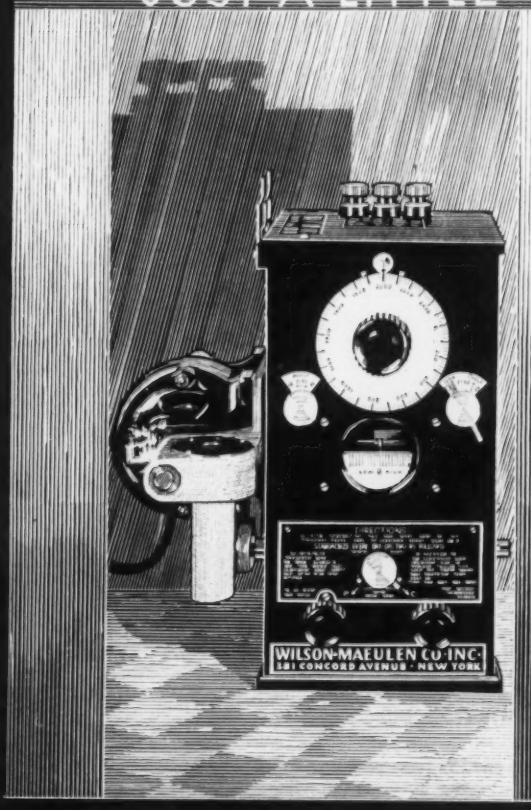

POTENTIOMETRIC PYROMETER CONTROLLER

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INSTRUMENTS
INDUSTRIAL — SCIENTIFIC

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Vol. 3, No. 11 NOVEMBER, 1930 Pittsburgh, Pa.

To Our Readers

WHICH ARE THE INDUSTRIAL INSTRUMENTS?

ALMOST interesting by-product of the serial publication of "The Handbook of Industrial Instruments" is the receipt of suggestions for including various instruments. Many writers evidence keen eagerness, as if they were sponsoring candidates for membership in an exclusive club. Being open-minded, the publishers of INSTRUMENTS and the author of the Handbook appreciate all such suggestions. In fact this is a request for more.

At the same time we wish to make it plain that the author's selections and rejections are never arbitrary, but always based on relative importance, on relevancy, and on practical value to engineers and plant executives, as set forth in his opening article last January. The question "*What* are industrial instruments?" resolves itself into a multitude of questions: Under *each* object of measurement, such as temperature, the specific question is and will continue to be, "*Which* are the industrial instruments?"

In other words, where to draw the line under each heading. But what are the headings? Which classes of measurements are to be included and which excluded? The recent manifestations of interest, brought to our engineering editor's attention, elicited the following memorandum:

> The answer to this question involves the state of the art. The scientific instrument of yesterday is the industrial instrument of today. A few years ago density was only measured by laboratory and testing instruments. Now there are instruments which not only continuously record the density of a liquid flowing from processing equipment, but control it automatically. These are industrial instruments par excellence.
>
> Today there are no industrial instruments pertaining to "Rockwell hardness"—all of them being testing instruments. Tomorrow one may be invented, and in a few years we may witness the production of bar and sheet stock whose hardness is controlled not in the laboratory but automatically during production.
>
> Perhaps that is why industrial instruments had never been defined before INSTRUMENTS and I undertook the job. Perhaps that is why no list of objects of industrial measurement and control had ever been attempted before I drew up the chart of the scope of the Handbook. Inasmuch as I wished to avoid the role of dictator and remain a reporter, this tabulation not only covered known industrial instruments but allowed for coming developments in the way of "industrializing" present-day laboratory testing and scientific instruments.

This "flexible" classification of all industrial instruments, on which the whole plan of his handbook is based, answers so many questions and suggests so many new discussions that we now publish it, on pages 656 to 658 of this issue—a year or more before completing the serial publication of the book . . . not in order to settle the matter once for all but, on the contrary, in order to elicit more suggestions from instrument makers and instrument users. Our readers are asked to observe the following directions:

1. Refer to the table.
2. Use a separate sheet for every heading. (A reader discussing instruments for viscosity, liquid level and area should use three separate sheets.)
3. Same for communications relating to instruments of classes not included in the table. (Thus, should a reader send information about two new industrial instruments, one relating to friction and one to flash point, he should use two sheets.)
4. State reasons for assertions, and give details such as instrument manufacturer's name, etc.
5. Name and address at the top of each sheet.

DRAFT OF A POSSIBLE CLASSIFICATION OF ALL INDUSTRIAL (& SOME OTHER) INSTRUMENTS ACCORDING TO OBJECTS OF MEASUREMENT OR CONTROL.

By M. F. Béhar

See Editorial on preceding page.

PARTIAL LIST OF OBJECTS of Instrumental Measurement or Control			EXAMPLES AND REMARKS		
Classes (Complete list)	Groups	Individual objects (magnitudes or quantities)	Some examples of various methods or MEASURING instruments	Some examples of automatic CONTROL instruments, or notes on control	Other remarks
1st column	*2nd column*	*3rd column*	*4th column*	*5th column*	*6th column*
I THE TEN industrial processing, working and operating **CONDITIONS**	**1. Thermal**	Heat (Q)	See Class II.	Heat is the property, temperature the condition	
		Temperature (M)	Thermometry: expansion, resistance, etc. Pyrometry: optical, thermoelectric, etc.	Thermometric controllers Pyrometric controllers	Distinctions between industrial and non-industrial instruments, and classifications of former, were given in previous articles.
	2. Hygrous	Absolute humidity (Q) Relative humidity (M)	Absorption, etc. Psychrometry, hygroscopy, etc.	Psychrometric and hygroscopic controllers	
	3. Pressure (*all M*) (a) Liquid and gas	Vacuum Absolute pressure Gage pressures— "low" "medium" "high"	Liquid head, Bourdon tube, inverted bell, bellows, etc. Also static or differential. Also classified according to range. Also primary or secondary types.	Most forms of automatic control devices (and greatest number in use) are not indust'l **instruments.**	The chapter on pressure instruments begins in the next (Dec.) issue. Suggestions entitled "Pressure" will receive earliest attention.
	(b) Miscellaneous	Plastic pressures Mechanical pressures	Cylinders, crystals, magnetic, elastic deformation, etc.	Apparently very little industrial automatic control	
	4. Flow (a) Fluids in pipes	Quantity (Q) Rate (M)	A. S. M. E. classification of methods (primary elements) will be followed. Also must consider classes of fluids in industries	Industrial viewpoint here requires classification distinct from that by primary elements as with flow **measurement.**	
	(b) Fluids in open	Quantity (Q) Rate (M)			
	c) Granular and materials	Quantity (Q) Rate (M)	Coal meters, etc.	Stoker feed control, etc.	See also under Weight.
	5. Liquid level, etc.	Liquid level Position.	Not only tank gages but all industrial position indicating and recording systems	Control usually indirect, flow being in most cases the controlled factor.	Under this head may be considered all remote indicating and recording systems.

	6. Electrical a) Current electricity	Quantity (Q), Current (M) Emf (M), Power (M), Energy (M), Power factor (M) Frequency (M), Phase, Etc.	Ampere hour meters, ammeters, voltmeters, wattmeters, demand meters, power factor meters, frequency meter, synchroscopes, etc.	Electricity is itself the essential condition in some processes. Examples: For current electricity: plating, refining, production of Cl, H_2, O, O_2, N, etc.; static electricity: Cottrell process; magnetism: ore separation, etc. Electricity is also the producer or regulator of non-electrical processing and operating conditions. Such is the criterion for "industrial" electrical instruments. Under this heading also come electrical details of pyrometers, tachometers, etc., for measurement and control of non-electrical conditions.	
	b) Static electricity	Quantity (Q), Potential (M), etc.	**Which** are the industrial instruments?		
	c) Magnetic	Quantity (Q), Flux (M), Intensity (M), etc.			
	7. Temporal	Time— Duration Sequence	Time recorders Operation recorders, chronographs, etc.	Timing controllers Sequence and "program" controllers	Timepieces are not ind'l instr's but clockworks are embodied in many industrial instruments.
	8. Speed	Angular velocity Linear velocity Angular acceleration Linear acceleration	Counters: Centrifugal, magnetic, electric, etc., tachometers; Tachoscopes, Stroboscopes, etc.	Only the industrial forms of speed control instruments—engine governors, etc. being excluded.	Only speed of parts, etc. Velocity of fluids and materials comes under I, 4—Flow.
	9. Chemical	"Strength" of processing medium: "Atmosphere," etc.	Classes of industrial instruments are exactly same as under II, 2.	Controlling potentiometers, etc.	Only condition of processing **medium,** not of processed material.
	10. Radiant energy	Visible: quantity, flux, intensity, illumination, insolation, etc. Ultra-violet X-rays, gamma-rays	Indicating and recording photometers, etc. Westinghouse UV ray meter, etc.	Visible light is not only a working condition but an essential processing condition, as in chemical processes. Ultra-violet irradiation of food products, etc., is now a recognized processing condition.	
	Miscellaneous	Acoustical	Supersonic energy, capable, for ex., of emulsifying mercury and water, may be considered a processing condition. Audible frequencies affect human output and hence come under working conditions. Many audiometers, etc.; few industrial.		
II PROPERTIES	1. Physical	Mass (M)	Industrial recording and registering scales, etc.	Control usually indirect, **speed** being in most cases the controlled factor	Ordinary indicating balances and scales excluded.
		Density (M)	Continuous indicators and recorders	Usually control of **flow** or **ratio.**	A.S.M.E. classifications of methods can apply to primary elements of industrial instruments for both of these objects.
		Viscosity (M)	Mostly testing instruments	Usually control of **composition**	
		Calorific value (M)	Recording calorimeters, etc.	Usually control of **composition**	

Classification of Industrial Instruments according to Objects of Measurement. By M. F. Béhar (Concluded)

Col. 1—Classes	Col. 2—Groups	Col. 3—Objects	Col. 4—Measuring	Col. 5—Controlling	Col. 6—Notes
II PROPERTIES (Continued)	1. Physical (Continued)	Color	No strictly industrial **measuring** instruments, but.....	Automatic sorters, graders, etc, with photometric primary elements.	
		Melting point..... Boiling point, etc..... Mechanical— Tensile strength..... Elastic limit, etc..... Hardness etc.....	Which are the industrial instruments?		
	2. Chemical	Alkalinity, pH, etc. when considered as properties rather than composition	Conductivity cells, etc. connected to electrical ind. & rec. inst's.	Controlling potentiometers, etc.	
	3. Electrical	Resistivity, permeability, etc.	No industrial		
III COMPOSITION	1. Physical (mech'l mixing)	Proportions, positions of ratio valves, dampers, etc.	Position indicators Special flowmeters Special recording scales	Automatic poidometers, etc. Most control systems are indirect: by flow, temperature and other processing conditions.	
	2. Chemical (compounding)	Analysis	Differential flowmeters, electrical remote indicators		
IV SIMPLE MAGNITUDES	1. Linear	Length, thickness, etc.... Area.....	Mech. and electr. indicators and registers. Planimeters	Thickness control by roll pressure control, etc. Control of length in continuous processing is speed control.	
	2. Angular	Revolutions..... Angular position.....	Rev. counters Position indicators		
V SIMPLE QUANTITIES	(There can only be one group in this class: **numerical** quantity)	"Number of—" "Production" "Traffic"	Mech., electr. and photoelectric counters, registers, totalizers, etc. For **rate** see I, 8.	Most forms of packaging machines and counting-loaders are not industrial instruments	
VI MISCELLANEOUS	1. Vibration	Frequency Amplitude	Vibrographs, vibration recorders, seismographs, etc.		
	2. Acoustical	Intensity, etc.	Audiometers, noise recorders, etc.		

The Handbook of Industrial Instruments

M. F. Béhar*

CHAPTER IX

Industrial Humidity Instruments

(Concluded)

6. Recording Instruments

One classification is given in Table IV, from which it may be seen that only psychrometric and hygroscopic recorders are on the market at the present time. Another classification, perhaps more convenient to users because based on records obtained, would be as follows:

1. Two-pen instruments which record dry-bulb and wet-bulb temperatures separately.
2. Single-pen instruments which record relative humidity:
   a. Psychrometric.
   b. Hygroscopic.
3. Absolute humidity recorders (thermal-conductivity).

(1). Two-Pen Recorders

Most industrial forms of humidity recorders are two-pen recording thermometers, one pen recording the temperature of a dry-bulb, the other pen recording on the same chart the temperature of a wet-bulb. These instruments may be self-contained for room use, or provided with a pair of flexible connecting tubes enabling the relative humidity of the air in a dryer, kiln, or other confined space to be recorded on a remote panel board. Except for the appearance of the bulbs (especially of the wet-bulb arrangement), these instruments are recording thermometers of either the pressure-spring or electrical resistance classes, and as such require no special description here, having been discussed in earlier chapters. The length of connecting tube and other characteristics of pressure-spring thermometer systems have been summarized in Table I. With resistance thermometers there are the advantages of long distances and of multi-switching possibilities. With pressure-spring systems, however, for longer distances than connecting tube limits, remote electric systems are in use; the wet-bulb and dry-bulb actuating a pair of transmitting mechanisms which in turn operate the two pens of the remotely located recording instrument.

Some instrument-makers recognize in their literature a distinction between recording hygrometers and recording psychrometers: If the bulbs are "stationary," that is to say, exposed to the circulation which prevails in the room, duct, kiln, etc., where they are located, the entire outfit is styled a recording hygrometer by these manufacturers; while if the bulbs are located in a pair of tunnels through which air is circulated at high and constant velocity by means of an exhaust fan, or if the wet-bulb alone is located in a spray chamber, then the instrument is listed as a recording

*Engineering Editor.

psychrometer. This is a logical distinction. All such instruments, of course, whether of the distance or wall form, are two-pen recording thermometers, which are all convertible from "psychrometer" to hygrometer" or vice versa according to the disposition of the wet-bulb, which may be called an accessory.

Nevertheless, while the wet-bulb arrangement is a minor construction feature as compared with the essential constructional elements of any two-pen recording instrument, it is of prime importance with regard to the purpose of the instrument. If such purpose is the exact measurement of humidity, the equivalent of a spray or aspiration psychrometer is preferable

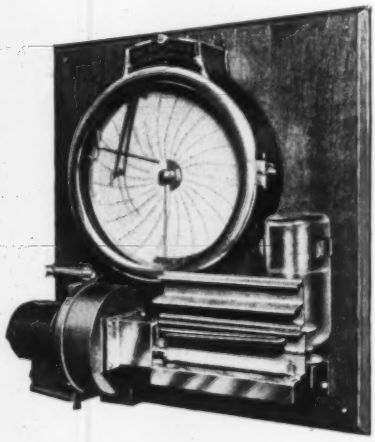
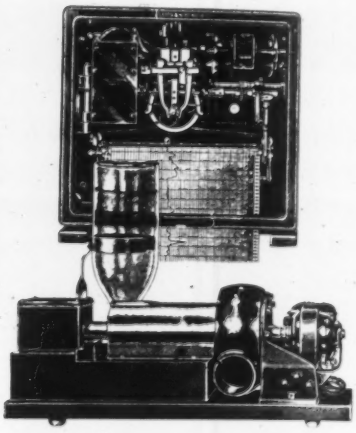


Fig. 185. Self-contained two-pen recording psychrometer with air tunnel cover raised to show bulbs. (*C. J. Tagliabue Mfg. Co.*)

Fig. 186. Direct-reading relative humidity recorder. (*Leeds & Northrup Co.*)



by far to the equivalent of a stationary hygrometer. Hence the variety of devices on the market pertaining solely to the bulbs. Instrument manufacturers have given a good deal of thought to this problem.

An arrangement of bulb tunnels and exhaust fan in connection with a dry-bulb and wet-bulb recording thermometer was first brought out, it is believed, by the Bristol Company even before Carrier and others demonstrated the unreliability of wet-bulb readings in still air. Fig. 185 shows a modern form of a self-contained two-pen recording psychrometer. Such instruments are made today by most manufacturers of recording thermometers and provide records whose accuracy is at least equal to that of the readings taken with a sling psychrometer, and whose value is greater.

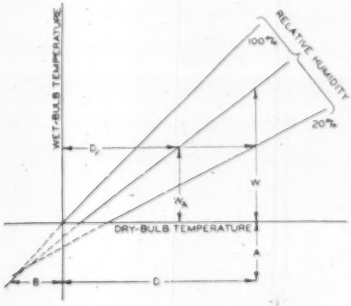
Improvements have also been made in recent years in the bulb brackets, wet-bulb moistening devices, etc., for the kiln or duct humidity recorders. The bulbs are now so attached as to be exposed to the prevailing circulation, instead of being placed in "air-pockets" as in some earlier models. Automatic reservoirs can now be relied upon to keep the wet-bulb coverings saturated at all times. Mention may be made, too, of the substitution, by the Foxboro Company, of a porous sleeve for the usual wick. Fig. 188

shows the usual construction of a duct or kiln hygrometer, consisting of a two-pen recorder, a pair of connecting tubes, and a bracket arrangement for the dry-bulb and wet-bulb.

A point worth remembering in connection with all distance hygrometers is that the temperature of the wet-bulb is *lower* than that of all or a part of the connecting tube which leads from the wet-bulb to the recording instrument. Therefore, when a vapor-pressure thermal system is employed, it must be of the "adjusted" class. In other words the spring must respond to the vapor pressure in the bulb regardless of vaporization effects elsewhere in the system.

HUMIDITY RECORDERS

Fig. 187. Diagram showing relation of dry-bulb and wet-bulb temperatures at various percentages of relative humidity. This principle is utilized in two-bulb direct-reading recorders, and also in some automatic relative humidity controllers. (*Leeds & Northrup Co.*)



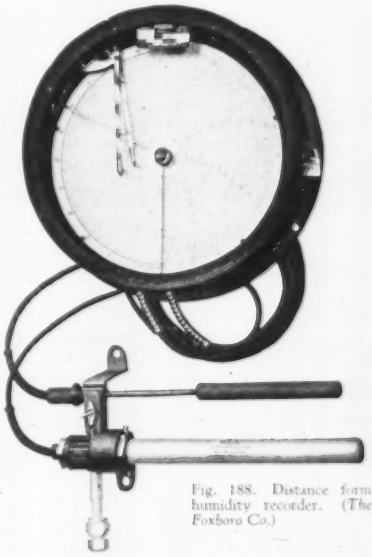


Fig. 188. Distance form humidity recorder. (*The Foxboro Co.*)

(2a). Psychrometric Single-pen Instruments

Brief descriptions were given under indicating instruments, of "effective temperature" thermometers in which the height of the mercury column depends on the temperature of the dry and wet portions of a single bulb. From a study of any psychrometric table it can be seen that relative humidity is a function of dry-bulb temperature and wet-bulb depression. Therefore it is possible to construct a two-bulb thermal system whose spring will deflect in proportion to the percent of humidity, provided only that the wet-bulb temperature be the true temperature of adiabatic saturation—which calls for a spray or aspiration arrangement. The application of this idea to recording thermometers of the mercury or gas-filled thermal system classes does not appear to have been exploited industrially, up to the date of writing. (With vapor-pressure systems, of course, connecting two bulbs to one spring would not serve the purpose—the only temperature recorded would be that of the hotter bulb.) On the other hand, its application to a pair of electrical resistance thermometer bulbs has been developed fully. The Leeds & Northrup Company has worked out the electrical circuit and placed on the market a relative humidity recorder which gives the

percent relative humidity directly. The electrical recording instrument is a potentiometer and the record is in the form of a strip-chart. (Almost all of the two-pen humidity recorders are of the round-chart type.)

Fig. 186 shows the complete equipment which is of the distance type and comprises two units—the recording potentiometer, which needs no special description here (this make of potentiometer having been fully described in the chapter on Temperature Recorders) and the wet- and dry-

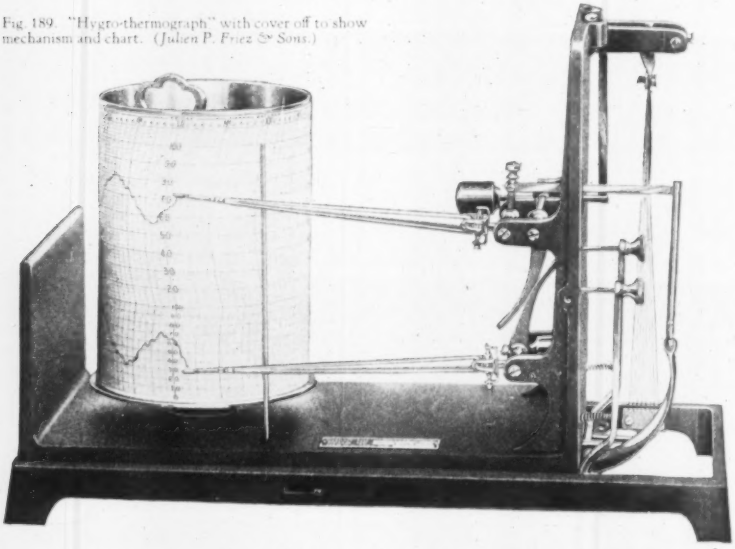


Fig. 189. "Hygro-thermograph" with cover off to show mechanism and chart. (*Julien P. Friez & Sons.*)

bulb apparatus shown in the foreground of the illustration. This device comprises two similar electrical resistance thermometer bulbs mounted in a tunnel through which a stream of the air under test is drawn by a small exhaust fan. Provision is made for keeping the surface of one of the bulbs wet.

The temperature-sensitive element of each bulb is a flat coil of pure nickel wire wound on a mica strip and laid between two similar strips to insulate it from the metal case which fits it closely. Each thermometer bulb is connected to the recorder by a cable of four conductors. Two conductors in the cable are connected with the terminals of the resistance thermometer-coil, and the other two are connected to the terminals of a compensating loop circuit within the thermometer case. With this type of connection the length and therefore the resistance of the conductors, and any change in resistance with change in temperature, have no influence on the record.

An explanation of the theory of the instrument, by its makers, now follows:

With the instrument here considered the relative humidity is determined from the temperatures indicated by two electrical resistance thermometers in a current of the air when one thermometer bulb is saturated with water and the other is dry. Since the humidity is completely defined by the wet-bulb and the dry-bulb temperatures, the problem is to make an instrument which will automatically compute and continuously record the relative humidity corresponding to these two temperatures.

The method by which this is accomplished is based on the relation between wet- and dry-bulb temperatures and relative humidity shown in Fig. 187. Wet-bulb temperatures are plotted as ordinates and dry-bulb temperatures as abscissae. Each slanting full line represents corresponding wet- and dry-bulb temperatures for one value of relative humidity. The wet-bulb temperature W and the dry-bulb temperature D locate a point on one of these lines.

If other temperatures WA and DA locate another point on the same line, the relative humidity is the same as for W and D. The temperatures W and DA locate a point on some other line and therefore indicate some other relative humidity. The important feature of the relation is that the humidity lines are accurately straight. For convenience it may be assumed that the broken line extensions all meet at the same point, although this assumption is not involved in the design of the recorder.

The slope of the lines uniquely defines the humidity, so that if the motion of the recorder pen is made to represent the slope, the scale of the instrument can be calibrated in percent relative humidity, and the record will show that ratio directly. Any corresponding wet- and dry-bulb temperatures, as W and D or W and DA, locate a point through which only one humidity line can be drawn. The slope of the line is defined by the relation $(W + A)/(W + B)$ in which A and B have the significance indicated in Fig. 187.

The recording instrument is a standard L & N Recorder for use with resistance thermometers, with a special combination circuit for recording relative humidity directly, within the limits of 20 and 100 per cent. Since the method involves evaporation of water from the wet-bulb, the lower limit of air temperature at which the equipment will record humidity correctly is fixed by the freezing point of water. The upper limit is about 175 deg. F. (80 deg. C.) dry-bulb temperature. Within this range the recorder is sensitive to a change of about 0.5 percent relative humidity. The limit of error in its performance is within 1.5 percent relative humidity.

(2b). Hygroscopic Recorders

Without retracting any part of the discussion on indicating hygroscopes in Section 5, it may be mentioned — now that we are discussing recorders — that the cost of the sensitive element of any recording instrument is but a small portion of the cost of the entire instrument. This practical commercial consideration is the reason why there are on the market several makes of dependable hygroscopic recorders. The careful selection, treatment and factory calibration of the sensitive element, which labor cost and competitive conditions would preclude in the case of indicators, are made possible in the case of recorders. Human hairs and strips of animal membrane are principally used in the industrial forms of such instruments. Considerable sensitivity is obtained. As to accuracy, owing to the nature of the primary element, it may be said to be "high but impermanent." That is to say, such instruments are capable of furnishing records of humidity within 0.5% of the true value — but only for a rather indefinite period following calibration. The subject being controversial, it may be closed with the remark that one source of information insists that hygroscopic recorders should be calibrated daily or at least weekly (depending on variations in temperature and relative humidity), while another reports instruments giving "satisfactory" records after several months of constant use without any adjustment whatever, and after years with but little attention.

Of the many hygroscopic recorders on the market, it is a pleasure to report that America now produces the best. A combination temperature and humidity recorder is shown in Fig. 189. The manufacturers assert that

"This instrument employs actuating elements selected long ago by the United States Weather Bureau as standard means for reproducing air conditions graphically. They are the bourdon tube for temperature and human hair strands for humidity. No recent scientific developments have disclosed a more practical nor more permanent means for translating changes of air temperature and humidity into mechanical motion than these two elements afford."

The humidity element is a set of processed human hairs. Note their "multiple banjo spread" arrangement. The temperature element is an alcohol-filled gold-plated pressure-spring of the bourdon tube form. Records are produced on five-inch wide daily or weekly strip-charts on which the relative humidity scale is 0 to 100% and the temperature scale either 10 to 110°F or —30 to +70°F. (Either range may be used on the same instrument).

(3). Absolute Humidity Recorders (Thermal Conductivity).

This is a recent development by the Leeds & Northrup Company and the following is abstracted from that Company's description of one instrument, especially made for the Bell Telephone Laboratories, capable of accuracy to one-twentieth of one percent relative humidity and sensitive to a change of one-fiftieth of one percent relative humidity, when the temperature of the air is 25°C.:

Two fine platinum wires are placed axially in two tubes of metal, and are insulated from the metal. One tube is sealed with dry air in it. The other tube is connected so that the gas to be analyzed passes through it and over the wire. The two wires are connected in a Wheatstone bridge circuit. The cell as actually used is shown diagrammatically in Fig. 190. The two tubes S and X are formed by drilling holes in a solid block of metal, and are .0375 inch in diameter and 4.5 inches in length. The wires are sealed into the tubes at the top by glass-platinum seals. Heavy platinum is used as lead-in wire; the fine platinum wire, 0.002 inch in diameter, is gold-soldered to the lead-in wires.

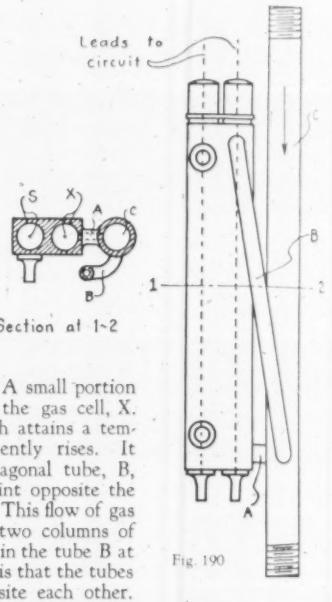


Fig. 190

The outstanding feature of the cell, as shown in Fig. 190, is the method of admitting gas to the X or analyzing wire. The gas sample is passed continuously downward through the tube C. A small portion of the sample passes through the tube A into the gas cell, X. Here it is heated by the fine platinum wire, which attains a temperature of approximately 210°C, and consequently rises. It passes out of the cell at the top, through the diagonal tube, B, and reenters the main gas-sample tube, C, at a point opposite the opening A through which it entered the cell X. This flow of gas is produced by the difference in weight of the two columns of gas—one in the cell X at high temperature and one in the tube B at lower temperature. The essential fact, however, is that the tubes A and B join the main gas-sample tube, C, opposite each other. Thus there is practically no pressure difference between the inlet and the exit of the cell X, and the flow through the cell X is dependent only on the platinum-wire temperature, being practically independent of the velocity of gas flow through the tube C.

It was desired to have the recorder accurate to ±0.05 per cent relative humidity over a range from 0 to 10 percent relative humidity at 25°C. Calculating the thermal conductivity of a mixture of water vapor and air at this upper limit of 10 percent at 25°C from the equation of Gruss and Schmick we obtain 1.00116 referred to air as unity. The difference between 1.0000 and 1.00116 represents the limits within which the recording apparatus should function. This range is determined, however, for the gaseous mixture at 82.2°C, while in the thermal-conductivity cell described here the mean gas temperature is about 100°C. Since the temperature coefficient of thermal conductivity of water vapor is not known, even approximately, it is possible only to estimate the sensitivity of the gas-analysis cell from the value derived from the work of Gruss and Schmick. A sensitivity of ±0.05 per cent relative humidity is therefore equivalent to a change of the order of 0.0000058 in the thermal conductivity of the gaseous mixture.

To use the range of the recorder to measure humidities other than those included in the narrow range of 0 to 10 percent relative humidity at 25°C it was found possible to calibrate the Kohlrausch slide wire in terms of relative humidity at 25°C. That is, by using the recorder galvanometer as an index of zero current condition (the recorder being set at zero on the scale), it was possible to plot a curve of slide-wire reading versus relative humidity at 25°C.

A multiple-range recorder was finally constructed, however, which enables the user to measure humidity using a single gas-analysis cell and recorder, in the following ranges: 0-10, 0-20, 0-50, and 48-98 millivolts. The first two ranges will cover from dry to saturated air at 25°C. The last two ranges are useful for measurements of high humidities at higher temperatures. The absolute precision and accuracy are, of course, reduced at the higher ranges.

On the 10 percent range the recorder is sensitive to a change of ±0.02 percent relative humidity at 25°C. The accuracy is ±0.05 percent relative humidity at 25°C. For an instrument of such a low range this accuracy is far better than any heretofore obtained on a self-recording apparatus, and is sufficient for the purpose for which it was designed. Further work in progress bears promise of increasing the accuracy by a considerable amount.

While the application of the thermal-conductivity method to the determination of water vapor is particularly successful where very low humidities are to be measured, it also should have a considerable field in applications where greater ranges of humidities are to be measured. This is particularly true where it is desired to measure and record humidities in an enclosure without introducing any water vapor by the use of the measuring apparatus, as would be done if the wet-and dry-bulb thermometer were used. The greatest advantage of this instrument is, of course, that it is continuous reading and no intermittent sampling is necessary as with other chemical analysis methods of humidity measurement.

Further uses for this thermal-conductivity humidity recorder should be found where it is desired to measure water-vapor content at very high or very low temperature. Above the boiling point of water the usual forms of humidity instruments or apparatus cannot be used. For example, the thermal-conductivity method might well be applied to the determination of moisture in high-temperature dry-kilns used in various processes. Likewise, even if the temperature or a gas mixture is below the freezing point of water, the thermal-conductivity method will still give reliable indication of the amount of water vapor present in the mixture.

7. Automatic Control

"Humidity control" generally means control of the relative humidity in a given enclosure, from a bench oven to a lumber dry-kiln, from a small room to a large building. Such expressions as "dew-point control," "wet-bulb control," etc., met with in the literature of the art, refer to specific means or steps toward the end which in every case can be expressed as control of relative humidity. In the present discussion "humidity control" will always carry this definite meaning.

Principles of Humidity Control

The physical principles involved in humidity measurement and contro have been discussed in Sections 1 and 4. It has been shown that the various relationships involved, once half-known qualitatively, are today known exactly and expressed quantitatively, thanks largely to the work of Carrier and other American engineers. With regard to automatic control some of the foregoing data on measurement can now be summed up in eight general statements which may possibly be called the principles of humidity control:

1. Control of relative humidity in a given space containing a *definite* quantity of water vapor (absolute humidity) cannot be attained without control of temperature.

2. Conversely, relative humidity control in such an enclosure can be achieved by regulating the dry-bulb temperature—the absolute humidity remaining constant. (The extent of such control is limited. For example, in round figures, starting with 50% humidity and 70°F. dry-bulb, the air would have to be cooled to 50°F. to obtain 100% humidity, and heated to 100°F. to obtain 20% humidity.)

3. In a given enclosure the absolute humidity will be increased by introducing water so finely divided that it rapidly evaporates. In thus

passing from the liquid to the vapor phase it not only increases the relative humidity but it extracts heat from the atmosphere (air-vapor mixture) and lowers the dry-bulb temperature. Exact control of humidity is obtainable by moistening control in such rooms, but only when the desired percent exceeds the normal and when temperature control is of secondary importance.

4. In a given enclosure the absolute humidity can also be increased by introducing jets* of steam but in this case the result is that both the relative humidity and the dry-bulb temperature are increased. This principle is applied today only in kilns, etc. (The days of its application in cotton mills have gone, it is hoped, forever.)

5. To *lower* the normal humidity within an enclosure requires special *apparatus* through which the moist air must be passed. Controlling instruments cannot do it alone.

6. Into an enclosure where there prevails a given room temperature and a given relative humidity, both conditions will be altered by the introduction of preconditioned air, the extent varying with the quantity, temperature and humidity of the introduced air which displaces the initial air. Similarly, when a given enclosure contains individuals, machines or materials (including the walls) which give off or absorb heat, or which give off or absorb moisture, or which do both in any combination, it is possible to maintain a desired temperature and a desired percent humidity by the introduction of properly conditioned air. This result is effected primarily by air-conditioning and artificial ventilation *apparatus;* the function of control instruments being to govern the operations of various parts of such apparatus.

7. With such apparatus and instruments, it is possible to maintain the desired percent humidity in a room, in spite of fluctuations in room temperature, by supplying *saturated* air whose *temperature* (dry-bulb, wet-bulb and dew-point all identical) is so controlled as to be at all times a definite number of degrees below the room temperature. Thus in order to hold at 50 percent humidity a differential of 20 degrees Fahrenheit is maintained: if the dry-bulb room temperature rises to 95°F. saturated air is supplied at 75°F.; if it falls to 68°F. saturated air is supplied at 48°F.—the result will invariably be the maintenance of the room humidity at 50%. In practice this principle is not applicable to certain industrial processing enclosures such as kilns or chemical apparatus where materials give off or absorb large quantities of moisture. It is effectively employed for industrial processing rooms served from one central equipment as well as for auditoriums, etc., and is known as "dew-point control."

8. All automatic humidity control instruments and devices must embody forms of sensitive or primary elements responsive to humidity changes. Such primary elements can be either psychrometric or hygroscopic. (See Table IV.) Psychrometric controllers embody thermal systems with primary elements responsive to temperature changes; hygroscopic controllers are not—in principle—affected by temperature changes except insofar as such changes effect changes in the humidity of the air to which the sensitive element is exposed.

*In this chapter we must use this term and restrict the use of "spray" to atomized water, in order to avoid confusion. In practice, labeling air line outlets of instruments "heating coils" and "spray" when the latter are connected to perforated steam pipes, does not lead to confusion because such instruments are designed especially for applications where humidity is increased by such introduction of steam.

The foregoing general statements or principles, constituting the fundamental background of humidity regulation, make it plain to see that automatic humidity controllers may govern or operate, directly or through relays, heating or cooling appliances, humidifying or de-humidifying apparatus, or combinations; but that they neither add* nor subtract water vapor, neither heat nor cool.

Thus in connection with dew-point control, which is a recognized and correctly styled application, there is no such *instrument* as a "dew-point controller."

Classes of Applications

The sharp difference in ultimate purposes between humidity control as applied to the processing of materials, and humidity control as installed for providing human comfort, is reflected in the different engineering methods, and the choice and disposition of the heating or cooling, and humidifying or de-humidifying, equipment—equipment which comprises apparatus and instruments. This difference does not in the least, however, impose a corresponding distinction between "processing humidity" control instruments and "comfort humidity" control instruments, except in minor details of construction or appearance: In that respect, of course, there is as much difference between a room wall "humidostat" and a "duct hygrostat," as there is between a wall thermometer and a duct thermometer or—to give a closer comparison—between a wall thermostat and a duct thermostat. The difference, nevertheless, is merely external. Essentially, *the principles involved are the same.* In considering humidity control instruments, and especially in classifying them from an engineering viewpoint according to functional likenesses and differences, there is no need whatever for starting off with such a division. This remark should not be understood as imputing criticism of manufacturers' booklets which do make such a distinction. These booklets, on the contrary, save the reader's time by putting the application first, which for their purpose is not only useful but logical.

Similarly, among the many humidity control instruments and accessories on the market, some are designed especially for use on air-conditioning equipment, others are designed for use where no such equipment is contemplated (except that the instruments themselves, once they are in operation, may be considered in that light), and others still are so designed as to be adaptable either to special air-conditioning equipment or to the usual steam and water supplies. But, again, these are not the engineering "classes" of humidity control instruments. And, again, it is admitted that manufacturers' booklets starting off with such classifications of applications are of convenience to purchasers.

As in temperature control, however, it is true that the application determines the class, type and form of instrument, and that in most cases the "instrument" proper is only a part of a control system.

A classified directory of industrial applications of humidity instruments is decidedly outside the province of this discussion. Broad classifications of these applications are in order, however, as they bear on the selection of control instruments.

*A psychrometric controller with primary elements of the "atomizing psychrometer" type *does* add moisture to the room, but the increase is negligible, and it so happens that this type of instrument is mostly installed where insufficient humidity is far more objectionable than an excess.

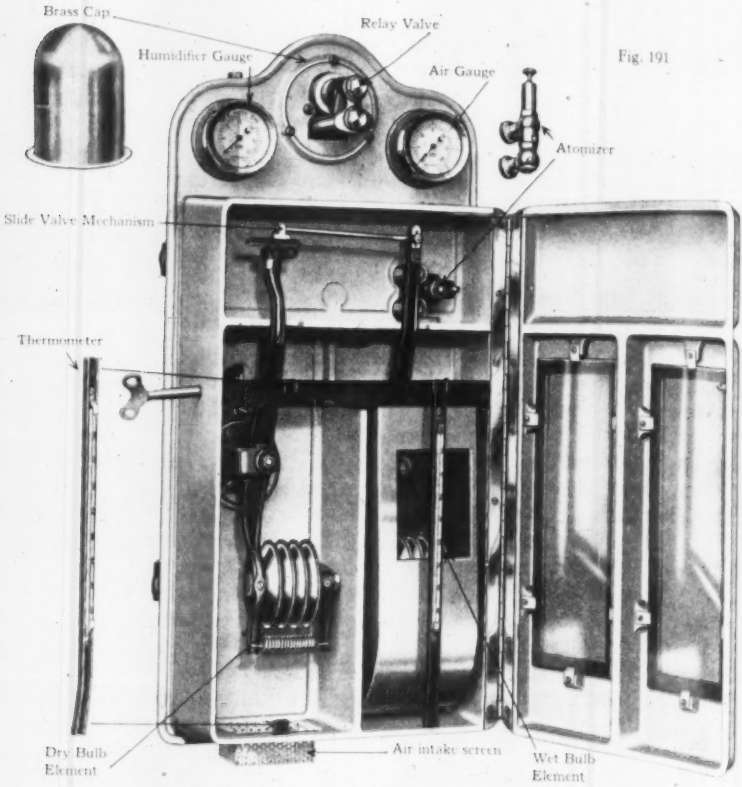


Fig. 191

Applications of instruments, with reference to the *location* of primary elements, which bears on the forms of instruments, panel boards, etc., fall into three general groups: (1) Rooms; (2) Ovens, Kilns, etc.; (3) Air conditioning apparatus.

With reference to the *conditions* which are to be controlled we have six general classes of applications of instruments:

(1) Control of "higher" humidity regardless of temperature—humidifiers providing the necessary additional humidity. Several sub-classes according to class and type of primary element, relay system, etc.

(2) Control of the *temperature* at one stage of an apparatus through which air is passed continuously. Sub-classes correspond (in this class only) exactly to the classes of temperature controllers.

(3) Control of the *humidity* at one stage of a continuous apparatus—several sub-classes here, according to the classes of devices operated by the controller: ratio dampers, sprays, velocity control, heating coils, etc. Still other sub-classes according to the form of primary elements, relays, etc.

(4) Control of heating source together with control of steam jets—in dry-kilns, etc. Usually known as "temperature-humidity" control. Sub-classes correspond roughly to the types of pressure-spring and other temperature control systems utilized. Instruments for this class of applications must necessarily be of "distance" forms.

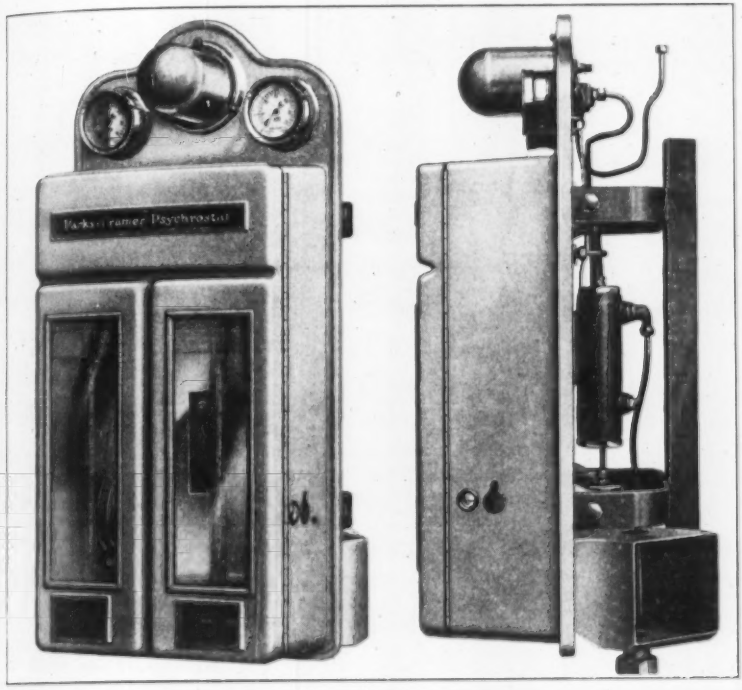
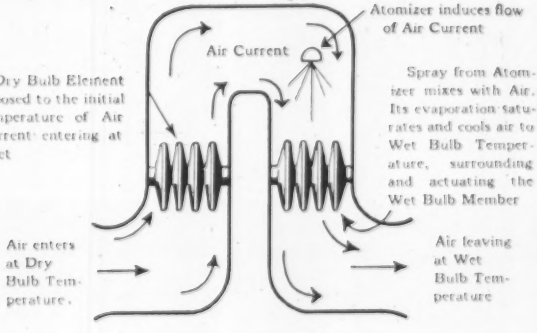


Fig. 192

Industrial form of humidity controller, the response of which to humidity changes is on the atomizing psychrometer principle. (Parks-Cramer Co.)

Fig. 193


Atomizer induces flow of Air Current
Air Current
Dry Bulb Element exposed to the initial temperature of Air Current entering at Inlet
Spray from Atomizer mixes with Air. Its evaporation saturates and cools air to Wet Bulb Temperature, surrounding and actuating the Wet Bulb Member
Air enters at Dry Bulb Temperature.
Air leaving at Wet Bulb Temperature

(5) Control of a *constant differential* between two temperatures of which the higher is variable and uncontrolled. Obviously this cannot refer to the "depression" between dry-bulb and wet-bulb, which varies with humidity. It refers to the differential between dry-bulb and *dew-point*, which is (within limits negligible in engineering work) a constant for any desired percent relative humidity. Such compound instruments must have one bulb exposed to room temperature but they do not control room temperature (See Principle No. 7 above). The second bulb is located in the path of the saturated air supply, and the system of relays actuates a number of valves, dampers, etc., in the apparatus, controlling water temperature, air mixing, etc., whereby the temperature of the saturated

air supply is held at a definite number of degrees below the variable temperature of the element installed in the room.

(6) All other compound applications calling for simultaneous control of two or more conditions by means of a plurality of control systems assembled in one case or on one panel.

From the brief references to sub-classes in the above summarized list, it is evident that a complete tabulation would be repetitious, inasmuch as standardized elements of control instruments and systems are suitable for

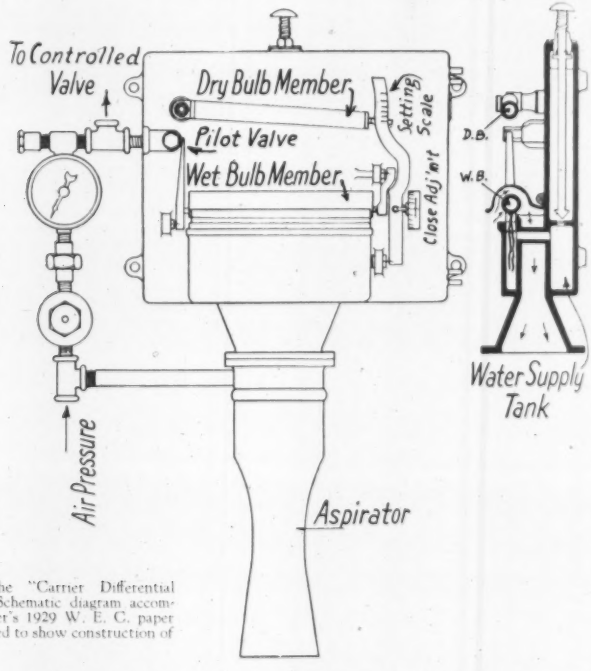


Fig. 194. The "Carrier Differential Hygrostat." Schematic diagram accompanying Carrier's 1929 W. E. C. paper but not designed to show construction of newer models.

three, four or five out of the six classes of applications. No need of an elaborate table, moreover, since manufacturers, knowing by experience which of the hundreds of combinations are *most* suitable, restrict their offerings to such combinations.

As in temperature control, it often is wise to consider first the mechanical work that has to be performed in operating plain or mixing or louvered dampers, plain globe or balanced or other valves, etc. At the same time there must be considered the mode of control, which varies from the straight on-and-off in the case of direct humidifier applications, to definite throttling modes with definite operating characteristics of the pneumatic or electric motor devices. Unless the entire installation be studied with regard to heating and ventilating or air conditioning engineering, one should not expect that the purchase and installation of a control instrument will infallibly result in providing the desired conditions.

To describe all relay systems and energized devices employed in humidity control would necessitate repeating the corresponding descriptions which have been given under temperature control. The reader must therefore

be referred back to Chapter VIII.* The present discussion concerns itself with those aspects of humidity control instruments which were not previously treated—that is to say with hygroscopic controllers and with specialized forms of temperature controllers.

Relation of Humidity Control to Air Conditioning

Another important point: Modern multi-stage air conditioning systems require not one but several automatic control instruments. Each thus becomes not only a part of its own control system but a member of a team, so to speak, known as "the controls," which must function harmoniously. In the chapter on temperature control, a discussion included a reference to "the controller fighting the valve." In modern humidity control installations the various controllers, while remaining "at peace" with their valves and dampers, must not "fight" one another. It is not amiss to diverge at this point from the specific subject of humidity control and deal briefly with pertinent aspects of the broader subject of air conditioning.

Air conditioning is officially defined as the *control* of atmospheric conditions within an enclosure with reference to temperature, humidity and cleanliness. (Aerologists lay stress on a fourth condition, velocity, of importance to human comfort.) Humidity is thus one of the three (or four) objects of control in air conditioning. Humidity control is only a division of air conditioning. It is not air conditioning and neither is air conditioning "nothing but humidity control" as is also widely but erroneously believed.

This does not mean that humidity control finds no applications apart from air conditioning. It finds many, especially in industry. Certain processes require applications of humidity control which do not necessarily call for the installation of specialized air conditioning apparatus. Only in a narrow technical sense can the installation of a hygroscopic controller, turning humidifier heads on and off in a paper storage room, be called an air conditioning installation. Likewise is it straining the point to say that air conditioning has been installed on a lumber dry kiln when there has been installed a temperature-humidity controller which is specifically a double-system temperature controller, essentially a pair of temperature control instruments each independent of the other.

Carrier's paper† at the 1929 World Engineering Congress assigned a definite and essential role to instruments. It is in order to quote and abstract from this authoritative treatise:

> Air conditioning equipment comprises:
>
> 1st. *Apparatus* for providing the necessary heat and moisture exchanges within the room to be conditioned and of the air supplied to the room to be conditioned and of the air supplied to the room for ventilation.
>
> 2nd. *Automatic devices* for governing such apparatus so that temperature and humidity be controlled within the limits desired. The latter are referred to as controls. Those for controlling temperature are known as thermostats, and those for controlling humidity are known variously as hygrostats, psychrostats, or humidostats.

It is noteworthy that the word "instruments" does not appear, and also that the "controls" include "thermostats" as well as humidity control instruments. But air conditioning *in toto* being defined as "control," the "apparatus" are also subservient to humidity control and must be considered. They will be briefly described at the end of this chapter.

*See INSTRUMENTS, July and August, 1930.

†The Control of Humidity and Temperature as Applied to Manufacturing Processes and Human Comfort, by Willis H. Carrier, Assisted by Committee appointed by Am. Soc. Heat.-Vent. Engrs.: Prof. A. C. Willard, W. L. Fleisher, S. R. Lewis, F. R. Still, O. W. Armspach, H. P. Gant, C. P. Yaglou, H. W. Ellis, F. C. Houghten and L. A. Harding.

Classes of Humidity Control Instruments

The logical custom, in engineering work, of considering instruments among the "controls" as adjuncts of humidifying, dehumidifying and other apparatus, necessitated the above classifications of applications and of apparatus. Humidity control instruments, considered by themselves, may be divided—as is done with instruments for controlling temperature, pressure, level, etc.—into four groups:

		See figures
(1)	Non-indicating humidity controllers	194-196,201-206
(2)	Indicating humidity controllers	191-193
(3)	Recording humidity controllers, also designated as humidity recorder-controllers	199,200,207,208
(4)	Indicating and recording humidity controllers, likewise known as humidity recorder-controllers	197,198

Another classification, also followed with temperature and other controllers, is according to necessity for auxiliary power:

(1) Self-operating humidity controllers, which operate valves and dampers directly. (None is described here.)

(2) All other humidity controllers, which actuate pilot valves, contactors and other forms of relays. The great majority of industrial humidity controllers fall into this group.

In describing and illustrating a number of the representative forms of industrial humidity controllers, we shall now follow the engineering classification by *types of primary elements*, that is to say, psychrometric (Figs. 191-200) and hygroscopic (Figs. 201-208). Various forms, under each type, need not be tabulated—the illustrations having been made to bring out such points.

Psychrometric (Atomizing)—In this type the primary elements correspond to a spray psychrometer. The wet-bulb, *not* covered with a moistened wick, is exposed to air which has been saturated adiabatically. In the instrument shown (Figs. 191-193) a continuous sample of the room air is first drawn over the dry-bulb as illustrated diagrammatically in Fig. 193 which gives the principle of the primary elements. In Fig. 191 the atomizer may be seen in detail, removed from its location inside the case. The bulbs are of the pressure-spring thermometric type and of the metallic-bellows form. Each actuates a lever. The differential motion of the two levers actuates a slide-valve air-leak which in turn actuates a relay valve in order to produce a sharp on-and-off mode of control of the humidifiers. The design of the mechanism is such that the position of the slide-valve, with reference to its seat, remains the same for the same percent humidity, regardless of temperature, within a temperature range extending above and below the extremes to which such instruments may be exposed in service. The side view, Fig. 192, shows the outlet of the air-saturating arrangement, where a visible mist indicates correct operation. The same compressed air supply which turns the humidifiers on and off induces the current of air and obviates the necessity for a motor-driven fan.

Psychrometric (Aspiration)—This type corresponds in its primary elements to the aspiration psychrometer. That is to say, the wet-bulb is largely shielded against radiation and is exposed to rapid and steady artificial circulation. Fig. 194 shows the principle of the Carrier psychrometric controller (not the construction of the newer models, however). This

instrument does not require an electric motor, the compressed air supply creating a downward suction in an aspirator provided with a constricted throat for inducing a very rapid circulation *across* the moistened wet-bulb—which is said to be an advantage over lengthwise circulation *along* a wet-bulb. The principle of control is the same as in the previously-described instrument—by means of an arrangement of

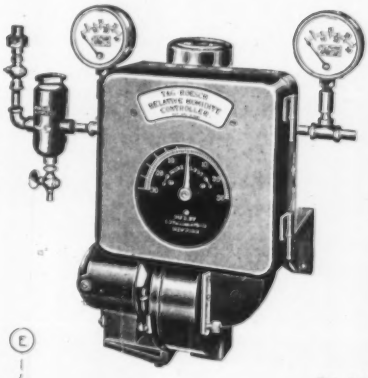


Fig. 195

Air-operated psychrometric controller of aspiration type. (C. J. Tagliabue Mfg. Co.)

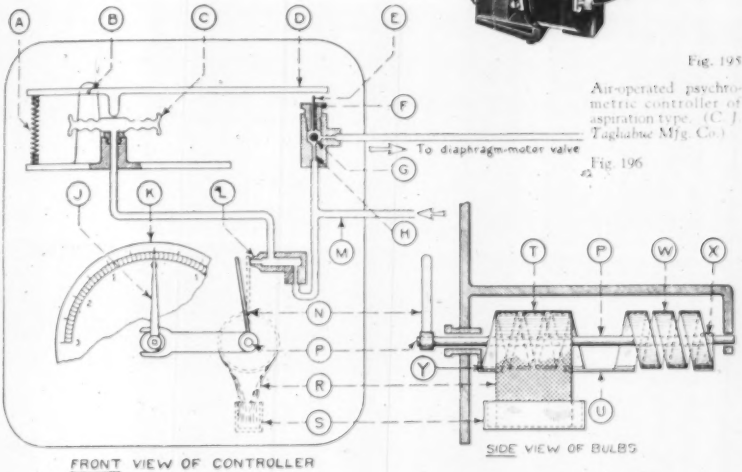
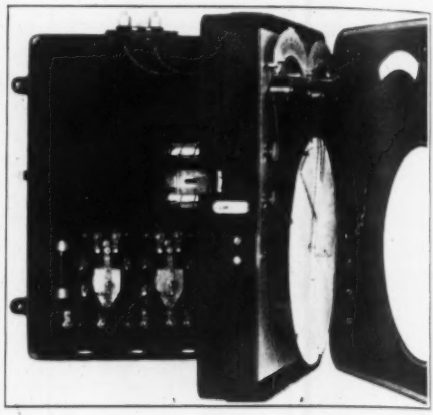


Fig. 196

levers. The Tagliabue controller, Figs. 195 and 196, operates on the same psychrometric principle but instead of an arrangement of levers it utilizes the differential motion of a pair of bulbs of helical shape, T and W, coupled in tandem by rigid fastening U. T is fixed at Y, and the free end of W is attached at X to the shaft P. Temperature changes affect both bulbs but in opposite directions, so that at 100% humidity, for example, temperature changes would cause connecting bar U to revolve around spindle P without causing rotation of the spindle. Fig. 196 is interesting in that it shows the system of "flapper" and air-relay valves employed in many psychrometric or hygroscopic humidity controllers, of various makes. The following may serve to clarify the operation of all such humidity control systems: When humidity tends to *increase*: flap N closes port L, capsular spring C is inflated, spring A is compressed, lever D rises, ball G rises off seat H, and compressed air shuts off humidifiers. When humidity is *too low*: L is open, C deflates, A swings D, pushing G on H, shutting off air to humidifier valve and allowing its *return* from the diaphragm and escape through vent F. With *no* air pressure on its diaphragm, the humidifier valve *opens*. (In some systems the operation is reversed, humidifiers being "on" only when air from controller to controlled valve is "on.")

Temperature-Humidity Controllers—This type belongs to the psychrometric class but the wet-bulb, instead of being exposed to artificial circulation, is located in the dry kiln or other controlled equipment, alongside of the dry-bulb. Moreover, instead of such controllers actuating only humidifiers, they control both the temperature and the humidity of the controlled enclosure. In other words, a temperature-humidity controller consists of two independent temperature control systems, one beginning at the dry-bulb and ending at the diaphragm-motor valve on the heating coil line, and the other beginning at the wet-bulb and ending at the controlled valve on the "steam spray" line. A few years ago, such controllers were non-indicating. Of late, the majority of makes have been recording; and Figs. 197 and 198 show a form which is indicating as well. This instrument embodies two indicating electric-contact type temperature controllers of the form shown in Fig. 115, and a two-pen recorder. Each bulb is connected to two helical pressure-springs—a controller spring which carries an indicating hand and contact arm; and a recorder spring which carries a pen arm. Thus there are two duplex thermal systems and the instrument as a whole is not a pair of temperature controllers plus a pair of recorder tube systems, but rather a dry-bulb set of controller-and-recorder system plus an independent wet-bulb set of recorder-and-controller systems. In each set, the recorder spring zero adjustment is sealed at the factory, and only the controller zero adjustment adjustable in practice. In this manner the chart records, while indicating the performance of the two temperature controllers, are in no wise affected by the mechanical and electrical operation of the latter except in that this operation regulates the dry-bulb and wet-bulb temperature of the controlled enclosure. This instrument is designed to operate the Bristol



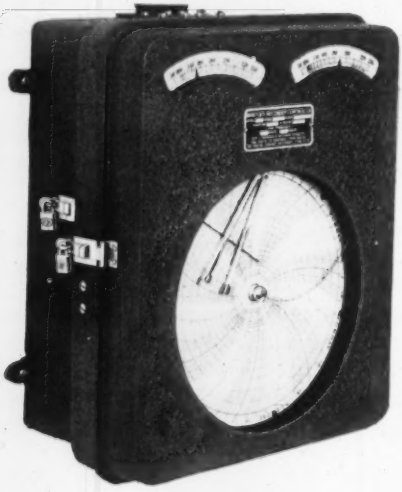


Fig. 197 (*above*) Mechanism of, and Fig. 198 (*left*) Temperature humidity recorder-controller with four helical pressure-springs. Electric operation of valves. (*The Bristol C*

"Type BK" electric motor valves on the heating coils and steam spray lines. These valves are of the indicating type with limit switches. They operate on line voltage through a relay panel which may be seen in Fig. 198, which shows the interesting hinged construction of this instrument, very much on the style of industrial pyrometric recording and controlling millivoltmeters and potentiometers Figs. 199 and 200 show the more usual form of industrial humidity recorder-controllers, in which form of instrument the Foxboro Company has long specialized. Compressed air is the medium by which the controlled valves on the heating and humidifying lines are operated. This instrument may be said to consist of a pair of independent

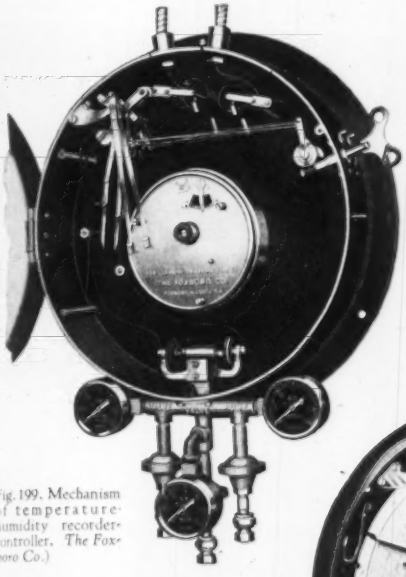


Fig. 199. Mechanism of temperature-humidity recorder-controller. *The Foxboro Co.*)

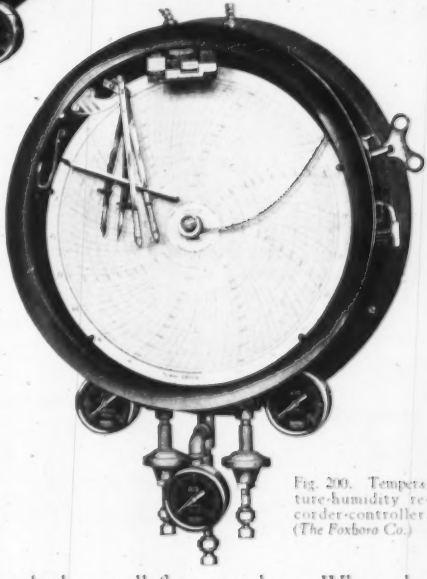


Fig. 200. Temperature-humidity recorder-controller. (*The Foxboro Co.*)

temperature recorder-controllers, of the general characteristics described in Fig. 127 and caption, but assembled in one case and recording on one chart. In Fig. 199, one may see by looking closely that the setting key can be inserted in either one of two openings in the upper right-hand portion of the case. Each index arm is set at the desired temperature. Attached to each index arm is an air leak, and to each pen arm is attached a small flapper valve. When the control point is reached, the pen arm is directly over the index arm and the flapper causes back pressure which operates a relay valve which in turn regulates the rate of air pressure change on the controlled valve.

Lack of space prevents showing and describing other specialized dry kiln controllers, some of which are remarkably ingenious. Brief mention may be made of the Taghabue "Inter-Myst" controller, with throttling air-operated dry-bulb control and on-and-off electrical humidity control having independently adjustable contact points so that the "swing" between them is adjustable. This adjustable swing, affecting the mode of control, is found also in some of the recent air-operated temperature-humidity controllers.

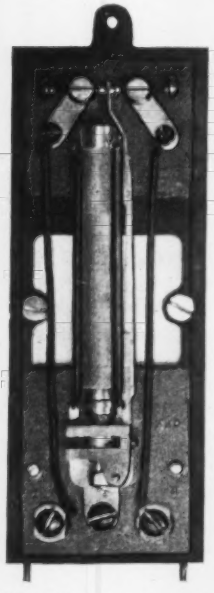


Fig. 201. Room "Humidostat" electric contact type. (Johnson Service Co.)

Hygroscopic Controllers—We come now to the type which makes up the great majority in plants, hospitals, schools and even residences. Every year finds an increase in the number of makes. The pioneer appears to be the Johnson Service Co. and one of its room-humidity controls is shown in Fig. 201. This is of the 3-wire, 2-contact control type and is designed to actuate a control switch. Its primary element is a cylinder of applewood. It is especially adapted for places humidified by electrically heated evaporators, such as small industrial processing rooms, botanical and agricultural applications, etc. Another electrical room humidity controller is shown in Fig. 203, which is largely self-explanatory. The primary element is in the form of a ribbon, 21 inches long, whose elongation and contraction is sufficient to operate a mercury switch, so that no relays are necessary when the solenoid valve,

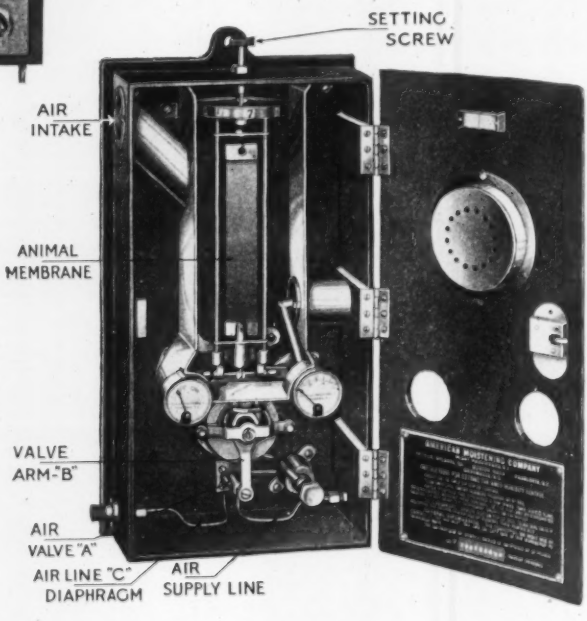


Fig. 202. Industrial form of air operated hygroscopic controller with induced circulation past primary element. (American Moistening Co.)

etc. requires not more than two amperes at 110 volts. The range of control is within 3%, factory setting. Calibrated for 45% relative humidity, this instrument will cut in at 42% and out at 48%. This "Humitrol" therefore is typical of the residential forms in which closeness of control is subordinated to other considerations. A contrast is now offered by the strictly industrial instruments shown in Figs. 202 and 204. The former is that of the American Moistening Co. which informs the author that "a

regular performance of control is a maintenance of humidity to within a 1° change in the wet- or dry-bulb reading." It is also said that "more than 100,000 laboratory tests of the membrane before its use proved its absolute reliability." The action is as follows: As the relative humidity decreases, the membrane contracts, opening valve A which allows compressed air to fill the bellows. The expansion of the bellows moves rocker arm B thus transmitting the air pressure through the air line C to the diaphragm-motor valve on the line which turns on the water supply to the humidifiers. Fig. 204 shows another representative industrial humidity controller employing a hygroscopic primary element—in this case strands of human hair, concerning which the manufacturer states "It will not pull out of shape nor acquire a permanent set. We experimented with all sorts of hygroscopic substances, but finally adopted the same hygroscopic element as is used by the Weather Bureau." Referring to Fig. 204 it may be seen that the lower end of the actuating element directly operates a flapper air valve, which is the starting point of a relay system similar to the others of that type described above. The upper end of the element is secured to a yielding spring so that unusually dry conditions will not strain it. Adjustment is obtained by turning calibrated scale, without changing the tension on the hair element. It will be seen that both instruments shown in Figs. 202 and 204 embody air ejectors which induce circulation of the room air past the primary element. This is a characteristic of the industrial forms designed for the rapid detection of changes in room humidity.

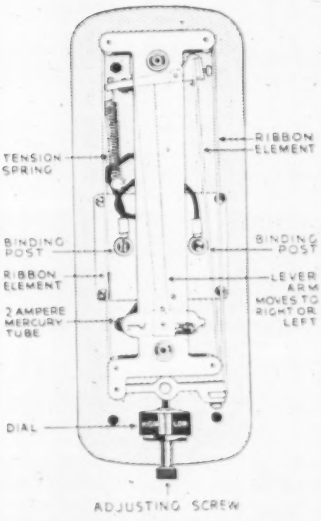


Fig. 203. Room "Humitrol," embodying mercury switch. (*The Lewis Corp.*)

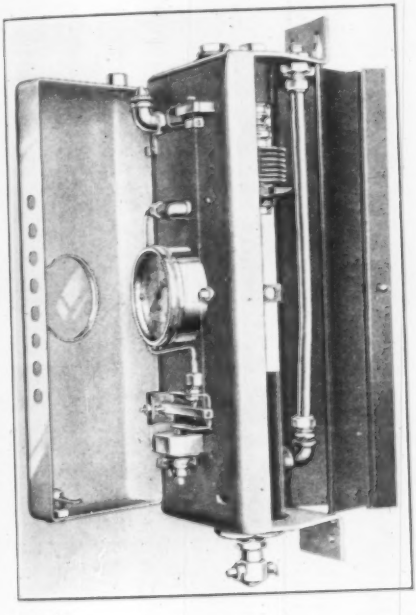
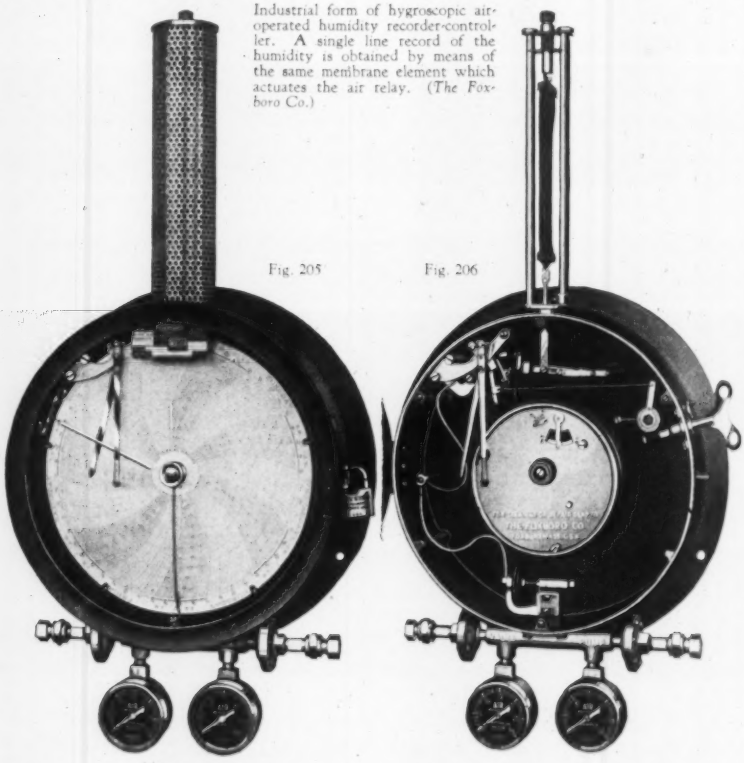


Fig. 204. Industrial form of air operated hygroscopic controller with induced circulation past primary element. (*Parks-Cramer Co.*)



Industrial form of hygroscopic air-operated humidity recorder-controller. A single line record of the humidity is obtained by means of the same membrane element which actuates the air relay. (*The Foxboro Co.*)

Fig. 205 Fig. 206

Hygroscopic Recorder-Controllers—The instruments described immediately above are non-indicating and non-recording. Figs. 205 and 206 show a relative humidity controller of the recording type. The primary element, made of animal membrane, is not subjected to artificial circulation but is enclosed in a perforated guard, which does not materially cut down the sensitivity. The chart is calibrated in percent relative humidity. As the illustrations show, this is an air-operated controller. The index arm carries an air nozzle and the pen arm carries a flapper, exactly as in the case of the temperature control instruments utilizing this principle. This instrument may be set to maintain relative humidity at any point between 20 and 90%. Setting is effected by turning the key, and the index arm then shows the setting point on the scale of the chart.

Compound Controllers—Reference was made above to the necessity for compound control systems in connection with air conditioning equipment. Figs. 207 and 208 show modern forms of such controllers, as used in conjunction with Carrier air conditioning equipment. Fig. 208 shows a typical Carrier temperature and humidity room control board. A is the hygrostat with a hygroscopic primary element exposed to the room air, B is the room temperature controller and C is a compressed air relay for the operation of dampers, valves, etc. A close-up of the hygrostat is shown in Fig. 207 which shows a control board for humidity alone. Both the temperature and the humidity controllers operate on the flapper air valve principle described above. The setting dial for temperature control is easily seen in Fig. 208,

the humidity setting dial can also be seen toward the top of the hygrostat in the right-hand portion of Fig. 208 and just a little above the center of Fig. 207.

Humidity Apparatus*

Resuming now the subject of air conditioning equipment, of which instruments are "the controls":—

There are two distinct groups of apparatus for effecting humidity changes: (1) Humidifiers used for the purpose of increasing the moisture content of the air and to produce cooling by evaporation; and (2) Dehumidifiers used for the removal of moisture from the air and to produce cooling by contact with water or surfaces at a lower temperature than the air.

Humidifiers may be divided into the following general types according to the method of operation:

1. Indirect (Introduction of moistened air).
2. Direct (Spraying into the room).
3. Combined (Direct and indirect).

Direct type humidifiers still find wide application, especially in textile mills. One of these types uses atomizer heads operated by compressed air in which the water is drawn into the nozzle and then finally atomized by a small jet of air under high pressure. In another type, water is supplied at high pressure (usually around 200 lbs. per sq. in.) to an atomizing nozzle located in a sheet metal enclosure suspended from the ceiling through which a current of air is caused to pass. In a third type of direct humidifying head a small jet of water is thrown upon a disc rotating at high velocity within a stationary cone of fine teeth against which the water thrown from the disc impinges. These three types of direct humidifiers do not provide either for controlled ventilation or for dehumidification.

Indirect humidifiers are similar in operation to the spray type air washers except that the water is sprayed directly against the incoming air. Such humidifiers comprise a chamber, usually from six to eight feet in length, through which the air is drawn at a velocity from 500 to 700 feet per minute. Inside the chamber one or more banks of spray nozzles create a finely divided spray through centrifugal action and require water pressures of from 35 to 45 lbs. per square inch. At the intake of the humidifying chamber is a set of baffles for distribution of the air and for preventing the spray from escaping from the chamber. At the outlet of the humidifier chamber an eliminator, consisting of a series of metal baffles, separates all of the free, unevaporated moisture from the humidified air. The air leaving the humidifier is thus completely saturated, but without any entrainment of unevaporated water particles. Such humidifiers are used only in connection with ventilating systems. They are practically always placed on the inlet side of the ventilating fan. Provision is made for warming the water in winter so that the air may be saturated at a definite temperature. The heating of the water is usually controlled by means of a fixed-stem duct thermostat (see figures 101, 103, 111, 116 and especially 126) placed in the path of the saturated air leaving the humidifier and controlling the heater through which the spray water passes. In other

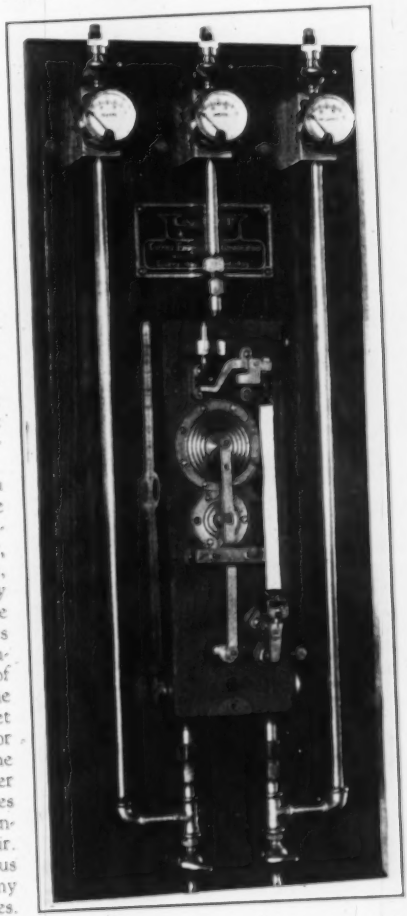


Fig. 207. Hygrostat panel used in conjunction with air conditioning equipment. (*Carrier Engineering Corp.*)

*Mostly abstracted from Carrier's paper, loc. cit.

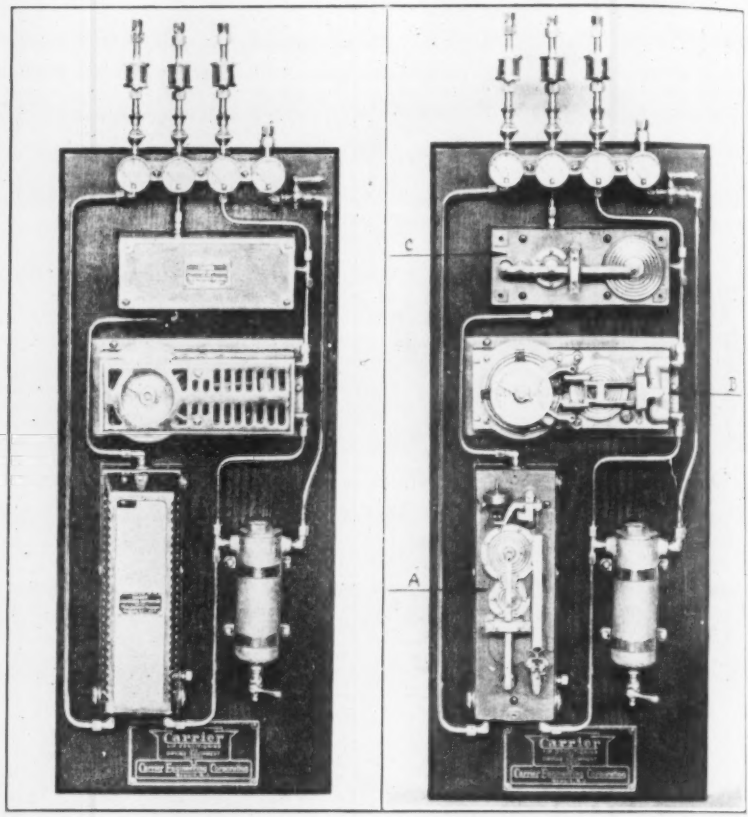


Fig. 208. Two views of a complete temperature and humidity control board used in conjunction with air conditioning equipment. (*Carrier Engineering Corp.*)

cases, particularly in industrial work where high humidities are maintained, the control of the dew-point temperature is effected by a duct thermostat controlling the *mixture* of outside air and return air from the building by means of fresh and return air dampers at the inlet to the humidifier.

In industrial work the dew-point regulation is effected in winter time by both of these means operating in conjunction.

In most industrial plant rooms little moisture is added to, or extracted from, the air in the room by the process carried on, and, as windows and doors are closed, conditions in the room rapidly stablize to the moisture content of the entering air. It is possible to control the relative humidity within the room by proportioning the *quantity* of the air supplied, in accordance with the heat sources. This is usually known as the "dew-point" method.

Another system is to vary the dew-point at the apparatus by means of a hygrostat placed in the room and so connected as to vary either the temperature or quantity of *spray water* used in the humidifier, or both. In air conditioning work this system is designated as the "direct relative humidity control."

Where large quantities of power are generated in a limited space, and where higher than 60% relative humidity is required, it is feasible and economical to use a *combination of direct and indirect humidification*. The indirect humidification is for the purpose of securing the desired quantity of ventilation and cooling and the additional direct humidification placed in the rooms to increase the humidity and at the same time, secure additional cooling effect. In general it may be stated that direct humidification is most satisfactory where higher humidities, with but little cooling or ventilation, are required.

A Chainomatic Balance for Measuring the Magnetic Susceptibility of Monel Metal

*Edward T. Post**

AS the temperature of a ferromagnetic substance is increased, there comes a point, called the critical temperature, at which it loses practically all of its magnetism. Iron has its critical temperature at about 790°, Cobalt, 1150,° and Nickel, 360°C.[1] One of the very interesting alloys, magnetically, is monel metal. It is found in a natural state, composed of about 67% nickel, 28% copper and 5% of other materials such as iron, silicon and carbon. The last 2 elements are introduced in the smelting process.[2] The critical temperature of monel metal is interesting because it occurs at a point so much lower than those mentioned above. Burrows[3] by a contact method placed the critical temperature of the specimens he used at about 95°C. By both a magnetometric and an oscillation method, Inglis[4] studied the changes in the permeability and the residual magnetism as the specimens of monel metal were carried through a range of temperature from 48° to 107°C. Inglis found by his oscillation method that, even at temperatures as high as 400°C., monel metal still had a permeability, measurably greater than unity.

This point seemed worthy of further investigation and so it was approached by a method totally different from that used by others for monel metal. McLennan and Wright[5] have described an excellent method which they employed in determining the susceptibility of other substances. It consisted in measuring, by means of a balance, the pull of a non-uniform magnetic field on a piece of ferromagnetic substance. In this present investigation it was found that an analytical balance, rebuilt as a "chainomatic" balance, gave a very convenient way for measuring this pull. The feature of a chain weight allowed a gradual addition or subtraction of the load balancing the magnetic pull. In Fig. 1 is shown the arrangement of apparatus.

A small cylinder, C, of monel metal was suspended by a fine wire from the bottom of the scale pan, P. This specimen of monel metal, No. 32, had a length of 1 cm., a diameter of 0.3090 cm., and a mass of 0.656 gms. It was attached to the suspending wire by a little basket made up of very fine wire. To eliminate side displacement, a heavy weight, D, (about 40 gms.) was attached below the monel metal cylinder by a continuation of the suspending wire. The monel metal cylinder was so hung between the poles of the electromagnet, M, that when the field was applied the cylinder was drawn toward the center of the field. It was this attraction of the magnetic

*Fayerweather Laboratory of Physics, Amherst College, Amherst, Mass.

[1]Wien-Harms. Handbuch der Experimental Physik, Vol. 1, page 307.

[2]"Monel Metal," page 5, Booklet by International Nickel Company.

[3]Burrows. Electrical World, Vol. 76 (1921) page 115.

[4]Inglis. Instruments, Vol. 2 (1929) page 129.

[5]McLennan & Wright. Physical Review, Vol. 24 (1907) page 276.

field for the cylinder which was measured as the temperature of the cylinder was changed. The weights of the cylinder, the basket and the mass D were counterpoised by a weight, W, on the scale pan P′. The variation of the attraction of the magnetic field for the monel metal could then be measured by the amount of the chain attached to the beam of the balance. The length of the chain thus suspended was regulated by the position of the slider, G. This slider moved up and down on a screw which was calibrated to read in terms of mass. Its constant was 0.002 gms. per turn of the screw

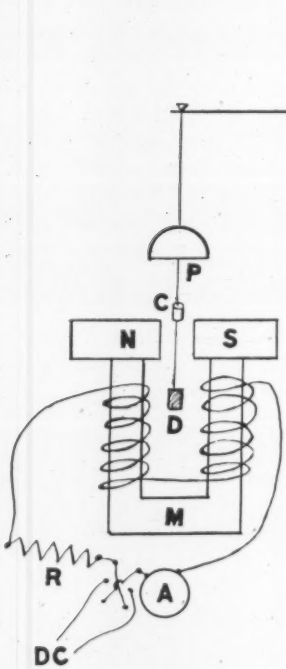


Fig. 1. A Chainomatic Balance arranged for measuring the Susceptibility of Monel Metal.

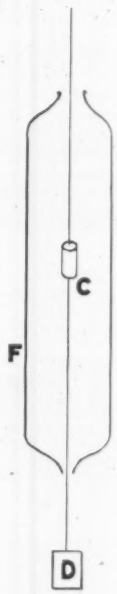


Fig. 2. The Pyrex Glass Tube on which was wound the Heating Coil of the Electric Furnace.

Changes in temperature of the monel metal were produced by a small resistance furnace. This is not shown in Fig. 1 but in Fig. 2. 140 turns of No. 22 manganin wire were wound on a pyrex glass tube, about 10 cm. long and 1.5 cm. in diameter. Before winding on the wire the glass tubing was covered with a layer of wet asbestos paper. The bare manganin wire sank into the wet asbestos so that when the asbestos was dry it served as an insulation between successive turns of the coil. Over the windings and the asbestos paper was spread a thick coat of asbestos cement which, in turn, was sheathed by a copper tube split longitudinally. The copper tube was fastened to a clamp in a ring stand for holding the heater in position about the monel metal cylinder. In order to prevent convection currents as much as possible, the glass tube was drawn down to small openings at

both ends, the upper end being just large enough to admit the cylinder and its basket.

A thermocouple was used to measure the temperature of the specimen. One junction was placed inside of the furnace and the other in an ice-water bath. The thermal emf of the couple was read by means of a millivoltmeter which had been calibrated to read in °C. In calibrating the thermocouple, one junction was attached to the bulb of a mercury-in-glass thermometer and placed in an oil bath whose temperature was carried up to 200°C. These readings were checked again against a standard platinum-iridium couple whose thermal emf was measured by a Leeds and Northrup potentiometer. With this outfit the thermocouple was calibrated up to 380°C.

The magnetic field of the electromagnet, M, was determined by a flip coil attached to a ballistic galvanometer, whose constant had been derived by means of a standard induction. The field strengths used, ranged from 318.1 to 358.7 gausses for the end of the cylinder nearest the center of the field. These values insured saturation according to Burrows. The field strengths at the other end of the cylinder varied from 284.3 to 318.9 gausses respectively.

The equation, which McLennan and Wright used in getting the susceptibility by means of the magnetic pull, was:

$$K = \frac{2gP}{A(H^2 - H_1^2)}$$

where K is the susceptibility, g the acceleration due to gravity, A the cross-section of the cylinder, H the field strength at the face of the cylinder nearest the center of the field, H_1 the field at the other face, while P is the pull in grams exerted by the field.

By observing the thermocouple readings, the temperature could be held constant while the value of P was determined. This was done over a range of temperature from 29° to 240°C. Fig. 3 shows the values of the susceptibility plotted against temperature. Curve 1 is for the minimum and curve 2 for the maximum field strengths observed. Readings were taken for four other field strengths between those shown in Fig. 3, the results of which, barring instrumental errors, fall within the range of those shown in curves 1 and 2.

It was established that not all the magnetism had disappeared at 140°C., thus confirming Inglis' work that there is no sharp critical temperature for monel metal. Between 60° and 100°C. it may be said that most of the magnetism of monel metal vanishes. Meschter working in this laboratory and using the same specimens of monel metal, studied their thermo-electric power against lead and also against copper. The specimen of monel metal, No. 32, noted in Inglis' paper, is weakly ferro-magnetic. Even in this specimen Meschter found a very marked inflection in the emf-temperature curve at a temperature of 90°C. This was very decisively confirmed by the more ferromagnetic sample of monel metal, No. 31. The method used by Meschter locates the critical temperature with greater accuracy than does the procedure described in this paper. Schulze,[6] in studying the

[6]Schulze. Zeitschrift fuer Metallkunde, November 1928; Tait. Transactions Royal Society, Edinburgh (1873) page 125; Belloc. Annales de chimie et de physique, Vol. 30 (1903) page 42.

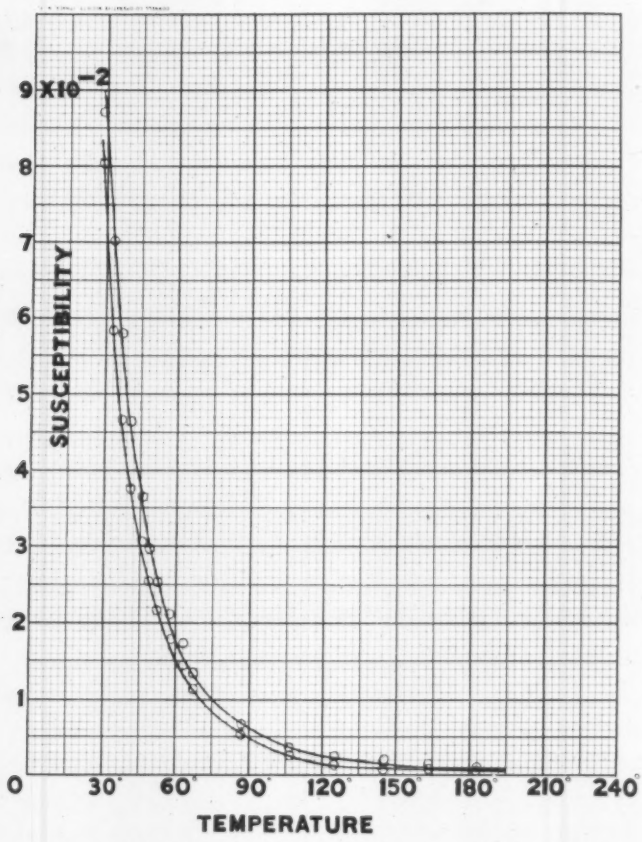


Fig. 3. Relation between the Temperature and Susceptibility of Monel Metal.

thermo-electric power of monel metal seems to have overlooked this critical point.

There were certain instrumental errors which had to be corrected as far as possible. Convection air-currents through the electric furnace produced a shift of the zero point of the balance. This was corrected by observing the deflection when no field was imposed on the metal. The wire by which the monel metal was suspended to the scale pan expanded some as the temperature increased. It was found that the wire from the grid of a vacuum tube gave so little expansion that this trouble could be neglected. The balance used in this work was a heavy analytical one and by no means the type to be used for paramagnetic substances. Even in this work the readings beyond a temperature of 140°C. were not so reliable as was desired. It has demonstrated, however, that the chainomatic feature of a balance is a very valuable adjunct to this method of measuring magnetic susceptibility.

Thanks are due Professor S. R. Williams for suggesting this problem.

Measurements

Industrial & Scientific

An Instruction Book for Engineers

DR. WALTER BLOCK

Eichungsdirektor der Provinz Ostpreussen

CHAPTER VIII. MEASUREMENT OF VOLUMES

(Concluded)

4. Water Meters

Only the operating chemist will have to face the problem of measuring flowing water or other liquids, a task occurring frequently in a similar manner when operating with gases. It will, therefore, be discussed very briefly only which possibilities exist for these measurements.

If one has to work with larger quantities of liquids it will generally be the simplest solution to let it run out of or run into a container and to measure the quantity in this container by means of suitable large scales. Should the quantities be too large or if such containers or scales are not available, other means have to be taken, namely, liquid meters which now may be discussed very briefly.

Principally two types of water meters are distinguished, also designated twater meters: current meter and volume meter, a distinction which, from the following description, will be quite understandable. A typical example of the first kind, at the same time also that example finds practically the widest application, is the so-called vane-water meter (Fig. 32). In the interior of the water meter housing a little light wheel of vanes is placed which rotates around its axis similar to the vanes of a wind-mill. The water running into the meter is so directed that it flows in the direction of the plane of the vanes and hits the vanes, as far at the outer end as possible, and rotates the wheel corresponding to the passing quantity of water. The faster the water flows the faster the wheel rotates. These rotations are transmitted to a counter which permits reading on a measuring disc directly the number of units of volume of water, generally in cubic meters and liters. It is clear that strictly speaking in this case the volume of the flowing water is not measured but that the apparatus depends essentially on the velocity of the passing water. It is up to the designer, in order to secure as correct a workng as possible that the jet of water hits the vane as favorably as possible. One distinguishes single-jet and multiple-jet meters which both can be considered as equivalent. Such a water meter operates better the greater the velocity, and its accuracy of measuring is naturally decreased when the velocity of water becomes smaller and smaller. It is obvious that for very slow flows of water (that is for consumption of extremely small quantities, of a small fraction only of that quantity which could pass the meter) the possibility exists that this slow flow does not develop sufficient power to rotate the measuring apparatus. A vane-water meter has, therefore, the tendency to give too small indications for quantities much below the rating, from which follows (which is very important for the application) that it is not directly possible to obtain

reliable indications also for other velocities if it has been calibrated for a certain velocity of flow. It will be best, if one has the assurance that the meter is right for a certain velocity to use it as near as possible to this velocity which should remain as close as possible to the maximum velocity.

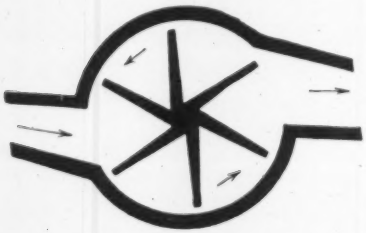


Fig. 32. Diagramatic Cross-Section Through a Vane-type Water Meter.

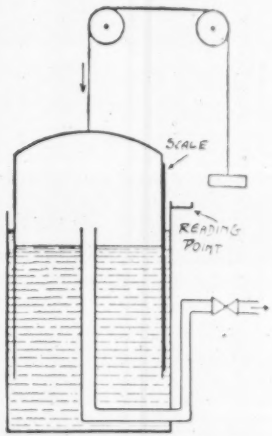


Fig. 33. Diagramatic Sketch of a Gasometer. (right)

In this respect, the two other types are much more favorable, they are pure volume water meters as they measure the passing water strictly by volume so that in a good construction practically no drop of water can pass without being measured. One drawback, however, also exists here as the operating resistance of these water meters is comparatively high so that for low velocities the meter might easily cut off the supply entirely. Their construction is somewhat difficult to describe, and it may therefore suffice to only give it very briefly. The measuring space of these meters is a cylinder or a cylinder with a spherically machined interior wall. In this space a second cylinder of equal height and about half the diameter moves which is closed tightly on the front sides and rotates in this space. This motion is made compulsory by the pressure of the inflowing water, and each revolution of the cylinder carries a definite amount of water through the space. Theoretically, it is impossible that water pass through without putting the cylinder in motion. This is the capsula water-meter. The circular motion of this capsula is, exactly as in the first type, transmitted to a counter and recorded. In the second type, the disc water meter, the measuring member is a disc the center of which in a stationary bearing is in the center of the measuring space, and which also rotates, and that in such manner that its axis describes a double-cone the common apex of which lies in its center. Otherwise, the same holds true as for the capsula meter. Both are two measuring devices which work very accurately; practically, of course, the possibility exists that a certain, though small negligible amount of water may pass through them as it is naturally impossible to make the movable parts perfectly water-tight. Besides, the two latter types are, even disregarding that they are much more expensive than the former, fairly sensitive to dirt which can easily obstruct and break the moving parts. This can hardly occur in the vane water meter. Two more points may be mentioned which are important: first, the largest

capacity of a water meter is that amount of water which can pass through it in each hour if the water runs out freely while on the other side the pressure of one atmosphere, that is 10 m. water gage, exists. A water meter for 10 m.^{3}, therefore, in one hour permits the passage of 10 m.^{3} if it flows out freely without back pressure while the pressure of the inflowing water is one atmosphere. Further: all types of water meters are not quite independent of the direction of the passing water which is especially obvious for the vane-water meter, and air bubbles are almost always wholly measured together with the water. It is therefore necessary to attach an air-separator; and in closed pipes, in which an air buffer exists behind the water meter which can often occur by liberation of air from the water, it can happen that surges take place in the pipe system at changes of pressure which means that the meter indicates an apparent flow of water just because it operates unsymmetrically although, in fact, no water has been used.

At the conclusion of this section may be briefly indicated the rather numerous devices, also for measuring liquids if the problem involves determining the existing amount of liquid in storage containers, i. e., when storing oil and other material in tanks or similar vessels. This can be done in different ways. In a very generally used method the storage container is provided with a gage and a scale on which the amount present can be read directly. Another method is that a float rests on the liquid the position of which is transmitted with tape or rope to a linear or circular scale. In all cases, however, it is difficult to obtain proper scale divisions because in the majority of cases the shape of the containers is influenced less from the point of view of their suitability for taking measurements than by that of the most favorable storing and assurance against leakage It will in all cases generally be necessary to provide the scale on each container individually which can be done in several ways.

5. Gases, General Remarks

The measurement of the volume of gases will only be treated here in extreme brevity because the literature on this subject already contains exhaustive publications on the measurement of large quantities of gases[5]. One may, therefore, be referred to this book for supplementing the following, and the mentioned publication will be extended here especially with regard to the measurement of gases in the laboratory mainly in so far as small quantities are involved.

6. Conversion of Quantities of Gases to Normal Conditions

As is known the volume of a gas depends to a very considerable degree on its temperature and its pressure. If we designate in the usual manner by v its colume, by p its pressure, and by t its temperature, these quantities bear to one another the well known relation:

$$p = p_o\,(1+\alpha\,t)$$
$$v = v_o\,(1+\alpha\,t)$$

and with these equations volume and pressure of each gas can be converted directly to standard conditions, that is the space which it occupies at the temperature of 0° and a pressure of 760 mm.Hg. To facilitate this conversion

[5]Chemische Technologie in Einzeldarstellungen: L. Litinsky, Messung grosser Gasmengen. Leipzig (1922).

for which a very great number of tables exist and especially also for the simultaneous transition from volume which the gas has under the prevailing conditions to the weight of the gas, a short table is given below which contains the most important numbers for this conversion. This table has been compiled not with the strict, but for common accuracies the fully sufficient assumption that the expansion coefficient of all gases is the same and has the value 0.00367 which corresponds, in accordance with the familiar laws of gases, to absolute zero (−273°C).

Tables to Reduce a Gas Volume to 0°C. and 760 mm.

(Volume v, Density d, Temperature t and Pressure p of a gas are related to the standard volume v_0 at $t=o$ and $p=760$ mm according to the equations:

$$v_0 = \frac{v}{1+\alpha t} \cdot \frac{p}{760}, \quad d_0 = d(1+\alpha t)\frac{760}{p}.$$

t=°C.	$1+\alpha t$	t=°C.	$1+\alpha t$	t=°C.	$1+\alpha t$	t=°C.	$1+\alpha t$	t=°C.	$1+\alpha t$	t=°C.	$1+\alpha t$
0	1.0000	21	1.0771	42	1.1541	63	1.2312	84	1.3083	105	1.3853
1	037	22	807	43	578	64	349	85	1.3119	106	890
2	073	23	874	44	615	65	1.2385	86	156	107	917
3	110	24	881	45	1.1651	66	422	87	193	108	1.3964
4	147	25	1.0917	46	688	67	459	88	230	109	1.4000
5	1.0183	26	954	47	725	68	494	89	266	110	1.4037
6	220	27	991	48	762	69	532	90	1.3303	111	074
7	257	28	1028	49	798	70	1.2569	91	340	112	111
8	294	29	064	50	1.1835	71	606	92	316	113	147
9	330	30	1.1101	51	872	72	642	93	413	114	184
10	1.0367	31	138	52	908	73	679	94	450	115	1.4220
11	404	32	174	53	945	74	716	95	1.3486	116	257
12	440	33	211	54	1982	75	1.2752	96	523	117	294
13	477	34	248	55	1.2018	76	789	97	560	118	331
14	514	35	1.1284	56	055	77	826	98	597	119	367
15	1.0550	36	321	57	092	78	863	99	633	120	1.4404
16	587	37	358	58	129	79	899	100	1.3670		
17	627	38	395	59	165	80	1.2936	101	707		
18	661	39	431	60	1.2202	81	973	102	743		
19	697	40	1.1468	61	239	82	1.3009	103	780		
20	1.0734	41	505	62	275	83	046	104	817		

p=mm	$\frac{p}{760}$	p=mm	$\frac{p}{760}$	p=mm	$\frac{p}{760}$	p=mm	$\frac{p}{760}$	p=mm	$\frac{p}{760}$	p=mm	$\frac{p}{760}$
700	0.9211	717	0.9434	734	0.9658	751	0.9882	768	1.0105	785	1.0329
1	224	8	447	5	671	2	895	9	118	6	342
2	237	9	461	6	684	3	908	770	1.0132	7	355
3	250	720	0.9474	7	697	4	921	1	145	8	368
4	263	1	487	8	711	5	934	2	158	9	382
5	276	2	500	9	724	6	947	3	171	790	1.0395
6	289	3	513	740	0.9737	7	961	4	184	1	408
7	303	4	526	1	750	8	914	5	197	2	421
8	316	5	539	2	763	9	0.9987	6	211	3	435
9	329	6	553	3	776	760	1.0000	7	224	4	448
710	0.9342	7	566	4	789	1	013	8	237	5	461
1	355	8	579	5	803	2	026	9	250	6	474
2	368	9	592	6	816	3	039	780	1.0263	7	487
3	382	730	0.9605	7	829	4	053	1	276	8	500
4	395	1	618	8	842	5	066	2	289	9	513
5	408	2	632	9	855	6	079	3	303	800	1.0526
6	421	3	645	750	0.9868	7	092	4	316		

In conversions of this kind one point has to be taken into consideration which must be mentioned particularly, namely the contents of humidity of the respective gases. For supplementing the following the future section on the measurement of humidity may be referred to. Humidity always exists in the form of water vapor, and it must be stated whether the gas is saturated with moisture or not. Each gas behaves in this respect in exactly the same way as air so that the familiar tables for air-humidity also hold for all other gases.

Dalton's law states the following: If several gases co-exist in a space they behave as if each of them were present alone. The total pressure of the gas mixture is therefore equal to the sum of the individual pressures

of the gases which they would exert if they existed alone in that space. This law is fundamental for the calculation of the behavior of gases and of humidity in gases. The whole conversion may be illustrated in the following by an example. 131 m.³ of gas at 19°C may have passed through a gas meter under a pressure of 42 mm. water gage, 756 mm. barometric pressure. The gas has been saturated with moisture, 42 mm. water gage equals 42/13.5 = 3 mm. Hg. The vapor pressure for 19°C is 16.5 mm. The pressure of the gas is therefore 749 + 3 − 16.5 = 735.5 mm. Consequently, its reduced volume is

$$v_o = 131 \cdot \frac{735.5}{760} \cdot \frac{273}{273+19} = 131 \div 0.968 \div 0.936 = 119 \text{ m.}^3$$

If the gas is dry the pressure naturally becomes 752 mm. and the calculation must be carried out accordingly. If it has a humidity of 60% the value of 0.6x16.5 must be used instead of 16.5.

7. Apparatus and Method for Measuring Gases

The actual methods for the determination of gas volumes as much as they are applied in the laboratory for small quantities of gas can be assumed to be familiar. These methods largely consist in the use of measuring apparatus of glass having a definite contents or being provided with scales and in which the gas is retained by a sealing liquid. These containers which are calibrated according to volumes coincide with the above discussed chemical measuring apparatus; they need not, therefore, be treated especially as they do not offer anything new in principle. It may only be mentioned that the official checking of these devices is carried out in the same manner as for the chemical apparatus, and also with the same limits of error mentioned before.

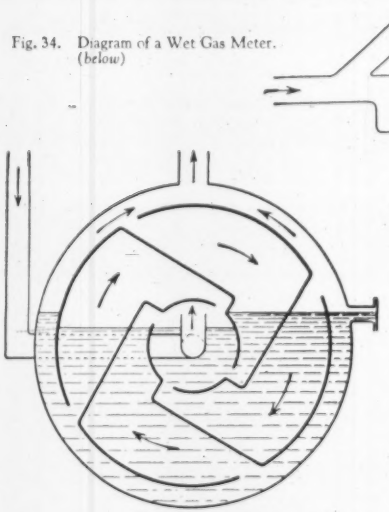
It must hereby be remembered that for the determination of the normal gas volume the latter is usually not below normal atmospheric pressure but is as a rule exposed to this and an additional pressure which is due to the sealing liquid. This additional pressure has to be determined under consideration of the kind of sealing liquid exerting the pressure. If it is water the height of the water column can simply be converted into mercury column by means of a table which is contained in the chapter on pressure measurement, and the pressure thus determined is added to or substracted from the barometric pressure read, and the total pressure determined in this way. If the sealing liquid is also mercury the method is obvious. Care must however be taken that the height of this column be determined with the necessary accuracy. With water this is not so important as the height determined only enters into the calculation after division by 13.5.

With other sealing liquids the method of calculation corresponds. The determined height is always to be divided by the density of mercury and multiplied by the density of the retaining liquid. This figure then is the correct one for the barometric pressure.

An important apparatus for the correct measurement of small and medium gas quantities as they are used in laboratories is the gasometer which at the same time can be used as a storage tank for the gas. It is shown diagramatically in Fig. 33. It consists of a cylindrical vessel of circular section filled with water. Into the water dips an inverted metal bell which is suspended on a chain over rollers. On the side the bell has a scale on which

the position of the bell and thus its volume can be read by means of a sighting device. The gas or air is in the interior of the bell and is conducted to the point of consumption by a pipe through the water. The bell is balanced by a counter-weight so that the gas escapes under a definite pressure. An additional device which will not be described in detail holds the gas flows under a uniform pressure even though the bell loses weight due to dipping deeper into the water. The scale permits directly reading the volume of the gas which has escaped from the apparatus. The pressure under which the gas escapes is naturally immaterial for the division but eventually must be considered if the gas expands after escaping.

Fig. 34. Diagram of a Wet Gas Meter. (*below*)



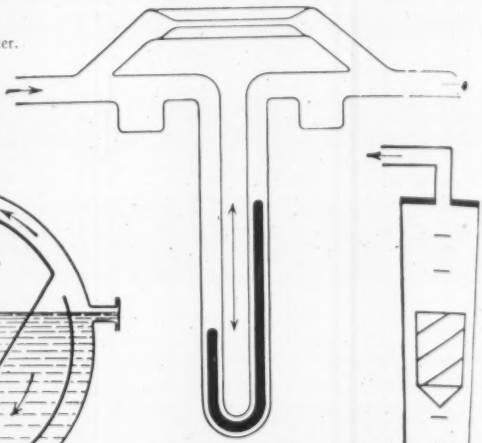


Fig. 36. Diagram of the Capometer. (*Riesenfeld.*)

Fig. 35. Diagram of the Rotameter.

Such gasometers can be bought in the smallest and largest dimensions and be used, according to the material of the bell and the sealing liquid, for different gases. They are, of course, not suitable for high pressures. While here the gas to be used is stored in the apparatus itself this is not the case when a gas meter is used for measuring the gas. In this case, the gas must in some way be pushed through the gas-meters under a certain pressure.

Two types of gas meters are distinguished, wet and dry gas-meters of which in the laboratory only the wet ones are used while the dry ones find industrial application. From the point of the measuring technique, the wet gas-meters are without question superior to the other.

A few words may be said of the dry gas-meters. In these, the gas flows through a series of chambers with movable walls. These walls are partly of metal, partly of cloth or leather which are made impermeable to gas. The passing gas presses these walls first to one side, then to the other, and by the movement of these walls a system of valves similar to the cylinder of a steam engine is moved and the gas conducted to one chamber after the other and the chambers opened to the outlet so that the gas can escape. As

the sizes of the chambers are not absolutely defined and due to the unfavorable properties of the movable parts of the chambers great accuracy cannot be obtained and later cause a change in their indications. Technically, these gas-meters have the advantage of not requiring inspection.

The wet gas meters, on the contrary, have very definitely limited measuring chambers. Their most important part is the rotating gas drum, often called Crosley-drum which is found, by the way, in almost exactly the same form in the well known capsula-mercury-air-pump. A diagramatic view of this drum is shown in Fig. 34. This drum revolves around a horizontal axis and is divided into four equal chambers. Each chamber has a slit for the inflow and for outflow which are opened one after the other by the sealing water. The gas flows through a pipe a little above the axis of the drum into the individual chambers and leaves by slits at the circumference and flows from here to the point of consumption.

Therefore, not only the volume of the drum is of importance but also the level of the water in the housing. As soon as the latter changes, the indications of the meters are also changed. The revolutions of the drum are counted so that one revolution corresponds to a certain amount of gas. It is obvious that no gas can flow through the meter without being measured. It is therefore important to keep the water level permanently at the same height. This is accomplished by a water tank which holds the water in the gas space proper always at such level that superfluous water is discharged by an overflow so that this determines the highest level of the water. As soon as the water level falls below a certain minimum a float on the water cuts off the gas flow. Laboratory apparatus which is supposed to be under constant supervision, generally has definite limits to which the water level is adjusted. The gas meter operates correctly when the water level is correct. With proper size gas meters of this type, small quantities of gas can also be measured but it should be remembered that it is unfavorable to drop below a full revolution of the drum. The so-called experimental gasmeters, however, have reading scales to enable one to read quantities below one revolution of the drum.

Such gas meters are built in quite different sizes. Technically they are in general, following an old custom, designated according to the number of flames whereby one gas-flame is assumed to consume 150 l. gas per hour. The smallest commercial size is the one for three flames with an hourly gas flow of maximum 450 l. which usually has a volume of the measuring space of 3.5 l. The maximum possible size of these gas meters is almost unlimited.

For the laboratory, there exist still quite a number of other methods for measuring gas quantities, especially for the case that a gas flows through a pipe line. Of these methods it can be stated in general that they are reduced to a measurement of pressure, and two principally different type of gas measuring devices, which are of importance for the laboratory, may be described here briefly.

First, the so-called Rota-meter type (Fig. 35) may be mentioned. It consists of a vertical glass-tube of circular section which increases slightly toward the top as indicated diagramatically in Fig. 35. In the tube is a cylindrical or conical float of such dimensions that it closes the bottom of the tube completely. The gas to be measured flows from below upwards and according to the quantity passing through, a varying pressure is exerted on the section of the float which is lifted correspondingly more or less. The

position of the float is therefore a measure of the passing quantity of gas, and a scale permits directly reading the quantity of gas which passes in a definite unit of time through the apparatus if the float retains this position during the whole time. In order to enable the float to adjust itself easily and freely it has spiral grooves on its sides so that it rotates slightly about its axis.

This type of gas meter which only permits measuring gas flow during a certain time-unit but never the total flow is built by many companies in different forms, it seems to be used especially for measuring compressed gas. For very large quantities this type must necessarily fail, as also for very low velocities.

The second type to be mentioned here is also based on a measurement of pressure and is represented by the Capo-meter (Fig. 36) according to Ubbelohde and Riesenfeld[6]. For constructions of this kind it is characteristic that the gas to be measured passes through a narrow glass tube and that the pressure difference between the two ends of the measuring tube is measured by a pressure meter, in most cases a U-shaped manometer, sometimes one meter in length. By proper selection of length and section of this capillary tube the range of measurement of such devices can be made very flexible and the accuracy of the measurement can also be increased by suitable dimensioning of the pressure meter. Particularly the arrangement of Riesenfeld which is made completely of glass and, for that reason, offers a certain advantage is used extensively.

These devices, however, have certain disadvantages. No proof is needed that these two latter devices depend in their indications on the density, temperature and pressure of the flowing gas. It is therefore not possible to directly test these devices simply with air and to convert their indications from this to other conditions. The conversion can be made by theoretical considerations but can hardly be recommended as the unavoidable inaccuracy becomes too large. It may also be mentioned that the one device provides directly an arrangement for measuring the viscosity of the gas. It will therefore be well to always test the whole arrangement in a preliminary test for the gas to be measured whereby the quantity which has passed is determined in some other way, most simply perhaps by collecting the gas in a container of known volume.

The dependence on the temperature is also very annoying so that Riesenfeld encloses the measuring capillary in a thermostat. With regard to a very similar arrangement the circular ring-manometer may be referred to, which will be described later in the book. It is an arrangement for the determination of the composition of flue gases.

For measuring larger quantities attention may be called to the above mentioned book in which particularly the large number of measuring methods is described in great detail, in which the measurement is reduced to a determination of velocity or pressure. In general, the following may be stated.

The methods consist partly in determining the distribution of velocity of the gas across the whole section of the pipe. From this and from the section of the pipe everything else can be calculated, eventually with the help of the measurement of time. For the measurement of velocity, anemometers with vanes or with a cross of half-spheres are used or instead of the latter the so-called Pitot-tubes which consist principally in that the flowing

[6] Ubbelohde and Hofsaess, Zeitschrift fuer Elektrochemie (1913) page 33 Riesenfeld, Chemiker-Zeitung (1913) page 510.

gas exerts, because of its velocity, a certain pressure in the interior of a tube which is arranged in the direction of the gas-flow. This pressure is called the dynamic pressure of the gas. At the same time the actual static pressure which exists independently of the gas velocity is measured by a second tube. From the difference between the two, the velocity of the gas can be determined.

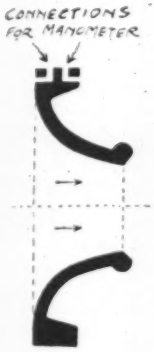


Fig. 37. Orifice. (at left.)

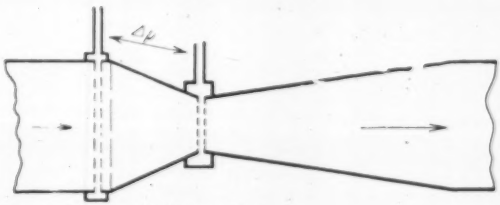


Fig. 38. Diagram of the Venturi Tube

One proceeds similarly if for example, an orifice, that is a circular disc with an opening in the center greatly reduces the section of the pipe. If the gas passes through this opening a difference of pressure takes place between the two sides of the orifice which is measured. From this difference and from the sizes of the free opening, a conclusion can be reached as to the passing quantity of gas. Instead of this arrangement, a nozzle also is used, or an intermediary piece which is inserted in the tube and offers somewhat simpler conditions and makes possible a more favorable measurement. The usual shape of such a nozzle is shown in Fig. 37. As a third type may finally be mentioned the Venturi-tube which, from a technical point, is the most favorable. In the diagramatical illustration of Fig. 38 it can be seen that the gas-flow is also narrowed down and then brought back again to its normal section; here also a difference in pressure is measured. This device has the remarkable advantage in comparison with the other methods just mentioned that practically no loss of pressure occurs in the pipe, which is unavoidable in the before mentioned methods.

In review it may be said that these two last methods indicate only momentary velocities and therefore give only quantities for a definite time unit. These devices are, therefore not directly applicable to indicate the total quantity of gas having passed through the pipe if the flow-velocity changes. They are to a certain extent load indicators and require in addition, special, sometimes very complicated devices for determining total gas quantity. Generally, however, they are connected with recording arrangements, and from the recorded curves the amount of gas which has actually passed in certain time intervals is then determined with a planimeter.

It is with deepest regret that we inform you of the sudden and tragic death of Dr. George Steiner, representative Eötvös & Rybar torsion bálances Dr. Steiner met his death in an aeroplane crash on Wednesday, October 8, 1930.

INSTRUMENTS BOOK SHELF

The books reviewed in this section can be supplied by Instruments Book Shelf, Instruments Publishing Company, Pittsburgh, Pa.

Principles and Practice of Flow Meter Engineering. *Foxboro Company*, Foxboro, Mass., 930. Limp black full-morocco, 5¼ by 8 inches, 248 pages. Price $2.00.

A handsome and informative practical manual which is not too large for the overcoat (or overall) pocket nor too deep for the practical meter man or chart computer. This is the first edition, dated April 1930, but our copy was not received until September, by which time it is hoped that the authors had already decided on changes which appear to be needed: It is a pity that this book, which contains such a wealth of practical information not only about the construction, use and repair of Foxboro Orifice Meters but also about the theory of thin-plate orifice metering and other subjects of general interest to flow meter users, should be spoiled by advertising matter. We have reference to the use of needless, obtrusive superlatives in some of the descriptions and to the inclusion of eight installation photographs (six full-page and two nearly so). To intersperse a valuable compendium with installation views that possess no practical informative value detracts from the excellent impression which such a book should make—and otherwise *would* make at first thumbing. Without this advertising the book would, in manner as well as in matter, live up to its preface, from which we quote the following:

> "Much of the original work on flow measurement was done by Foxboro Engineers, and when the problem arose of preparing this volume we turned to our own engineering staff. This is their book and we believe it to be much more complete than any yet published elsewhere on the subject."

Examining the book part by part and section by section the impartial reviewer is forced to conclude that as soon as he has done his duty in calling attention to these blemishes that stick out like sore thumbs, the remainder is not only meaty but written in a delightful simple style. For example, Section 5 of Part 3, "Fundamentals of Commercial Measurement" is a 20-page treatise which alone makes up for the advertising photograpas. Another example is the directions about the purification of mercury—four pages of "dope" for meter maintenance men which fill a real need.

The mathematical treatment of flow measurement has been simplified to such an extent that practical meter men who never took algebra or calculus can understand it, absorb it and remember it—which is a very good thing for the industries that depend on orifice flow meters. In that respect the book might be called "The Chart Computer's Pocket Companion."

The ingenious gas flow nomograms or alignment charts on pages 110 and 111 make it possible to determine, by the use of a straight edge, the size of orifice to give a certain differential at a given flow, static pressure and gravity, thus saving tedious calculations. They also make it possible to determine by the same graphic method the flow through a given orifice when the static pressure, differential, plate coefficient and gravity are known. The same comment applies to the specific gravity chart which is tipped in opposite page 49, and also to the chart for liquids on page 58. Still another example of helpful information deserving of commendation is the brief discussion of the error caused by neglect of two-pen time lag in computing charts. We never realized it could amount to 42% of the gas charged to a consumer in a given period!

Whether this book is "much more complete than any yet published elsewhere on the subject" depends entirely, of course, on what "the subject" is: Westcott, Spitzglass, Hodgson, Lichty, Ower and other authors are certainly not relegated to obscurity. But taking everything into consideration, "Principles and Practice of Flow Meter Engineering' is a welcome accession to fluid flow measurement literature because it covers its particular subject in a highly creditable manner.—M. F. Béhar.

Die Thermoelektrische Temperatur-und Wärmeflussmessung. *E. Raisch & K. Schropp.* Forschungsheim für Wärmeschutz, Munich, 1930. Paper, 6½ x 9½ inches, 93 pages, 11 figs. Price 6 RM.

The first part of the book covers the thermoelectric measurement of temperature. The authors point out in the preface that this subject has been covered in a number of treatises but include it here because the second part of the book, covering the thermoelectric heat flow meaurement, is built up on the former and the two measuring methods are closely allied.

In the second part, the theoretical considerations, the requirements to be met by heat flow meters as well as their application, are covered. The development of the heat flow meter is covered. Information on the performance of the tests is also given.—R. Rimbach.

Impurities in Metals. *By Colin J. Smithells.* John Wiley & Sons, Inc., New York, 1928, Cloth, 157 pages, 166 figs. Price, $5.00.

This book is of practical value to users and manufacturers as well as advanced students of metallurgy. The following important chapters are included in the contents:

> Methods of Studying the Structure of Metals; X-rays and the Structure of Metals; The Structure of Pure Metals; The Structure of Alloys; The Influence of Minor Constituents on Structure; The Influence of Minor Constituents on the Mechanical Properties of Metals; The Influence of Minor Constituents on the Electrical Properties of Metals: The Influence of Minor Constituents on the Corrosion of Metals.

Ample illustrations, tables and charts serve to make clear the text. The reviewer calls attention to a correction on line 13, page 54; the sense seems to require "liquid" instead of "solid."—Richard Rimbach.

Measurement of Air Flow

E. OWER, B.Sc. (LOND.), HONS.I., A.C.G.I.
Bramwell Medallist; Member of the Institution of Heating and Ventilating Engineers; Assistant in the Aerodynamics Department, National Physical Laboratory

CHAPTER VII.

THE VANE ANEMOMETER.

ALTHOUGH it is subject to certain practical limitations, which will be indicated later, the vane anemometer has been extensively employed for many years. As a means of measuring wind speed, particularly in the range of low speeds, where, as we have already seen, such small pressures are set up by the motion that their accurate determination becomes a matter of considerable difficulty, its simplicity renders it an exceedingly useful instrument; and if properly used it is capable of giving all the precision ordinarily required in engineering practice.

The vane anemometer is, in effect, simply a windmill, consisting of a number of light flat vanes mounted on radial arms attached to a common small steel spindle which rotates in two jewelled bearings. Eight vanes, made of thin sheet aluminium or aluminium alloy, are almost invariably used; they are inclined at an angle to the axis of the spindle, which is set along the wind direction when the instrument is in use, and the wind forces acting on the vanes cause the spindle to rotate at a rate depending mainly on the air speed.* By means of suitable gearing the motion of the spindle is communicated to a pointer, or, more usually, to a number of pointers moving over graduated dials. Normally, the dials are marked with scales of feet, and experience has taught manufacturers of these instruments how to proportion the various dimensions, vane inclinations, and gearing ratios, so that the number of feet indicated on the dials in unit time is approximately equal to the distance traversed by the wind in the same time, i.e. to the wind speed. In order, therefore, to determine the wind speed it is only necessary to observe with the aid of a stop watch the time taken for a number of feet of air, as shown by the indicating mechanism, to pass the instrument. This gives the "indicated" wind speed, from which the true air speed is

* See below for the effect of air density.

obtained by the aid of the calibration curve for the particular anemometer in use.

Instruments of this type are mainly of value for measuring air speeds in large ducts or ventilating shafts, or in smaller pipes (subject to the restriction as to the limiting size mentioned below) where access can conveniently be made to an open end, preferably an outlet end. They are probably best used when mounted on light rods and inserted into the airstream from one side. It is important that the observer should not stand too close to the instrument whilst readings are being obtained, as his presence will disturb the conditions of flow even if he is

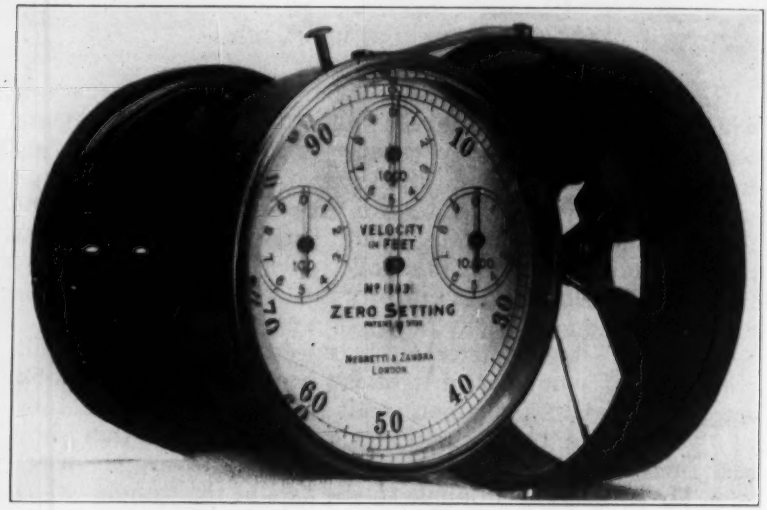


FIG. 31.—Vane anemometer.

situated downstream of the position occupied by the instrument. In order to determine the quantity of air flowing, readings must be taken with the axis of the vane circle at a number of points across a section.

Two types of anemometers in common use are illustrated in Figs. 31 and 32. In the former the plane of the dial is perpendicular to the plane of rotation of the vanes; whilst this design is not so compact as the other, it is probably to be preferred on account of the greater facility which it offers for taking observations from the side.

In many instruments provision is made for throwing the indicating mechanism into gear or disconnecting it from the vane spindle by the movement of a small lever. In some instruments, also, the reading can be set to zero at any stage. These devices would appear to be designed to obviate the use of a stop watch, readings presumably being taken by throwing

the indicating mechanism into gear at a given instant and disconnecting it when a certain time has elapsed. This method of using vane anemometers is not to be recommended; more accurate results will certainly be obtained by observing with

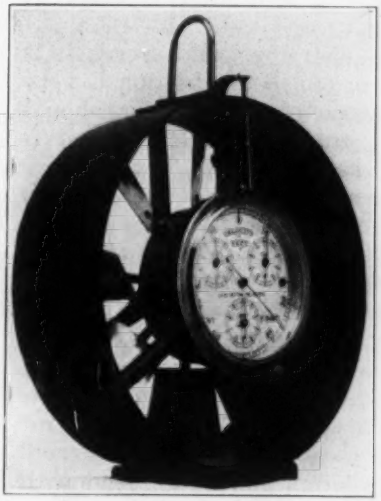


FIG. 32.—Vane anemometer with concentric dial.

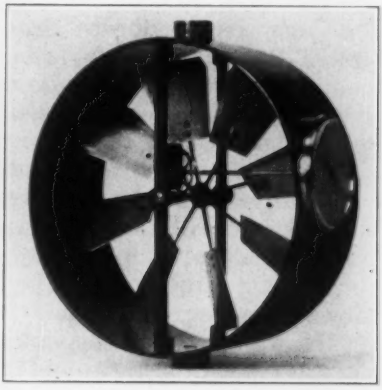


FIG. 33.—Author's low-speed vane anemometer.

a stop watch the time taken for a given number of complete revolutions of one of the pointers. The other method should only be adopted if a stop watch is not available. In order to reduce starting and stopping errors to small percentages of the total readings, no observation should occupy less than 60 seconds, or involve a reading of less than 100 feet on the instrument. It is advisable also to take two check readings of every observation, as it will often be found that the flow is subject to fluctuations, so that the average over a given period is not quite constant.

It is often stated that vane anemometers are unreliable and that their indications are subject to unaccountable inconsistencies. The author's experience with these instruments does not support this contention. Trouble frequently arises through the use of an anemometer to measure wind speeds for which it is not designed. If the speed is too high, the vane setting may suffer a permanent distortion which will cause a corresponding permanent alteration in the calibration curve. On the other hand, if the speed is too low the friction of the bearings and gearing exercises an appreciable effect (see below). The normal types of instrument, such as those illustrated in Figs. 31 and 32, are suitable for the measurement of air speeds ranging from about 5 to 50 feet per second, and may con-

fidently be relied upon over this range. For higher speeds, special instruments are made which are either of heavier construction, or, alternatively, incorporate a device by means of which the quantity of air actually passing through the vanes can be reduced ; such instruments can be used for wind speeds up to 100 feet per second or more.

Low-Speed Anemometers.—For low wind speeds it is essential to have an instrument in which the friction is very small. In order that the wind torque causing rotation should be large compared with the resisting frictional torque it is desirable that the vanes should be large and set at a large radius from the axis. These dimensions are, however, limited by considerations of lightness, for if the inertia of the moving parts is too great the instrument will not follow rapid fluctuations in the speed of the wind and will give readings which differ perceptibly from the mean wind speed. Moreover, it must be remembered that the resisting frictional torque is composed partly of a torque due to the weight of the moving parts, and partly of a torque due to the end thrust of the spindle on its downstream bearing, arising from the down-wind component of the wind force on the vanes ; the first of these factors will increase with the weight of the vanes and the second with their size. As is usual in design generally, a compromise has therefore to be effected between conflicting requirements.

A form of low-speed anemometer which gives consistent readings down to wind speeds of about 0·6 feet per second was designed by the author and described in the *Journal of Scientific Instruments* for January, 1926. This instrument is illustrated in Fig. 33. The vanes are of the usual pattern, inclined at an angle of 45° to the axis, the outer radius of the vane circle is $1\frac{1}{8}$ inches, and the vanes are $1\frac{1}{8}$ inches deep. All gearing is eliminated with the exception of a worm drive through which the rotation of the vanes is transmitted, with a reduction of 50 to 1, to a pointer moving over a dial attached to one side of the casing. The pointer is fixed directly to the worm-wheel spindle, and the only markings on the dial are four short radial lines, as shown, at the ends of two mutually perpendicular diameters. The calibration of the instrument is given in terms of the relation between the wind speed and the revolutions per second of the pointer over the dial. Three tapped bosses are fitted to the casing (the third, which cannot be seen in the photograph, is opposite to the dial) for convenience in mounting the instrument to suit various conditions of use.

It is important to observe that every anemometer should be calibrated in a wind whose speed can be controlled and measured by independent means, or by moving it at known

speeds through still air, for it is not possible to predict the readings of an instrument from its mechanical constants. Until recently, instruments were frequently sent out by the makers accompanied by a printed form stating that a certain number of feet per minute must be added to the readings to give the true wind speed, the number being the same for all speeds. Such instructions should be regarded with suspicion and not accepted without verification. During the course of a large number of calibrations of vane anemometers carried out under his supervision, the author does not recollect a single instrument whose error was constant over the whole range.

The method of carrying out an anemometer calibration is in itself a simple matter, but considerable care must be taken to obtain an air stream suitable for the purpose. In cases where the amount of work necessitating the use of an anemometer does not warrant the provision of special testing equipment, the instrument may be submitted to the National Physical Laboratory for calibration.

Readings in an Inclined Wind.—The readings of a vane anemometer do not appear to be seriously affected by fairly large variations of the direction of the wind from its normal path perpendicular to the vane circle. Whilst it is not possible, on account of the numerous differences in details of shape and construction that occur amongst existing types of vane anemometers, to draw generalised conclusions from the observed behaviour of a particular instrument, Fig. 34 will serve to show what order of error may be expected if the wind is inclined to the axis of the vane circle. The results relate to experiments carried out by Messrs. F. C. Johansen and W. J. Duncan with a calibrated anemometer of more or less normal proportions. The instrument was mounted in a wind tunnel side by side with a second calibrated instrument which served as a standard. A sufficient distance was allowed between the two instruments, which were situated in the same cross-section of the tunnel, to render negligible any interference one might have on the other. Simultaneous readings of the two instruments were taken, the standard being kept stationary in normal attitude and indicating the true mean speed over the intervals of observation, whilst the other was rotated successively to the wind direction, by stages of 5° or 10° at a time, through large angles on each side of its normal attitude. At each setting the indicated speed of each instrument was observed, and the ratio $\frac{V_\theta}{V_s}$ was calculated, V_θ being the speed as given by the yawed instrument at an inclination $\theta°$ and V_s the true wind speed as indicated by the standard.

It will be seen from Fig. 34, where $\frac{V_\theta}{V_s}$ is plotted against

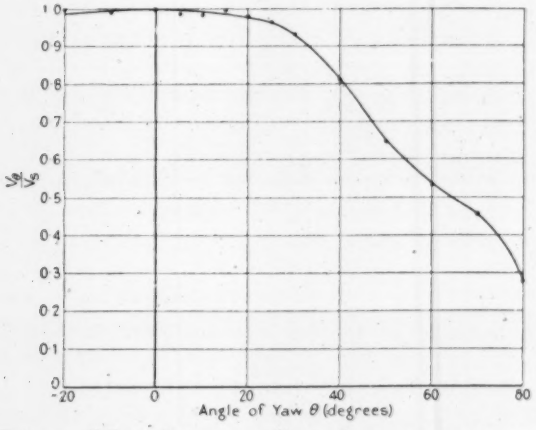


FIG. 34.—Effect of yaw on readings of vane anemometer.

θ, that the instrument could be yawed through about 20° before an error of 1 per cent. on the indicated speed was incurred. It would appear therefore that little apprehension need be felt as to the accuracy of the readings of a vane anemometer if the mean direction of the air current is not known within fairly wide limits.

Characteristics Indicated by Theory.—The theory of the vane anemometer will be considered in the second part of the present chapter, but since the theoretical treatment is unavoidably somewhat involved, it will be useful at this stage to state the main deductions to which it leads. Under normal conditions an anemometer is generally used to measure wind speeds appreciably higher than the lowest speed which will just set the vanes in rotation In these circumstances it is found that the effect of friction at the bearings can be neglected, and it will be shown that the rotational speed of the vanes will then depend only on the velocity of the air and not on its density. The readings of a well-made anemometer, in which the frictional resistance is very small, do not therefore require correction for atmospheric pressure and temperature provided that the vanes are not rotating too slowly. For special low-speed work variations of the density of the air may, however, become important, and should be taken into account by the method shortly to be described.

As we have already seen in dealing with the flow of air in pipes, there is in general a variation in velocity from point to point across a section of a pipe, from which it follows that when an anemometer is used to measure the speed of air flowing along a pipe there will usually be a variation of wind speed across

the anemometer disc. Theory shows that under these conditions the anemometer does not indicate accurately the speed of the filament of air passing through the centre of the disc, and that quite important errors may arise from this cause. It appears therefore that, in order to avoid such errors, the diameter of the anemometer should be fairly small in comparison with that of the pipe, so that the variation of speed across the instrument itself is small. Unless precautions are taken to equalise the velocity at different points along the pipe diameter, if a marked variation originally exists, an anemometer should not be used in a pipe whose diameter is less than about six times, preferably eight times, that of the instrument.

Measurement of the Rate of Flow in Pipes with Vane Anemometers.—Like the Pitot tube, the vane anemometer measures a local velocity which, subject to the limitations mentioned above, may be taken as the velocity of the filament of air passing through the centre of the vane wheel. In order, therefore, to determine the quantity of air flowing along a pipe by the use of this instrument, readings of velocity must be taken at a number of points across the section whose positions are determined in the manner indicated in Chapter V.; in other words, readings must be taken with the axis of the vane wheel at the points at which the velocity head would be observed if a Pitot tube were being employed for the purpose. If v_1, v_2, v_3, etc., are the air speeds in feet per second thus observed, the mean speed is given by

$$v_m = \frac{1}{n}(v_1 + v_2 + v_3 + \ldots),$$

where n is the number of readings taken.

The volume of air flowing in cubic feet per minute is

$$V = 60Av_m,$$

where A is the area of the pipe section in square feet, and, since 1 cubic foot of dry air at 60° F. and 29·92 inches of mercury barometric pressure weighs 0·0763 pound, the weight of air flowing in pounds per minute is

$$Q = 60Av_m \times 0{\cdot}0763 \times \frac{b}{29{\cdot}92} \times \frac{520}{460 + t}$$

$$= 79{\cdot}6Av_m \times \frac{b}{(460 + t)}$$

where b is the barometric pressure in inches of mercury and t is the temperature of the air in the pipe in degrees Fahrenheit.

It should be noted that in this equation b is the pressure of the air (in inches of mercury) in the pipe, so that the remarks

made in Chapter V. regarding the allowance that must be made for the static pressure in the pipe if this exceeds 8 inches of water above or below atmosphere, apply also to cases in which the vane anemometer is used. It is, however, very unlikely that such static pressures will be experienced in any practical case in which the vane anemometer can conveniently be employed.

The Theory of the Vane Anemometer.*

Aerodynamic Characteristics of Flat Plates. — The vane anemometer consists of a number of small flat plates inclined at an angle to the direction of the wind; let us therefore consider the system of forces that acts on a flat plate when exposed to an air current. In Fig. 35 AB represents an end view of the plate inclined at an angle α to the wind direction, this angle being usually termed the angle of incidence of the plate.

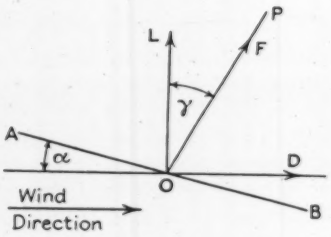


Fig. 35.

Let V be the wind speed, ρ the density of the air, and S the area of the plate. Experiment shows that the aerodynamic reactions in the plate may be reduced to a single force F acting along OP, the point O, whose position along AB depends upon the incidence α, being known as the centre of pressure. It is found also that OP usually makes a small angle γ, as shown,

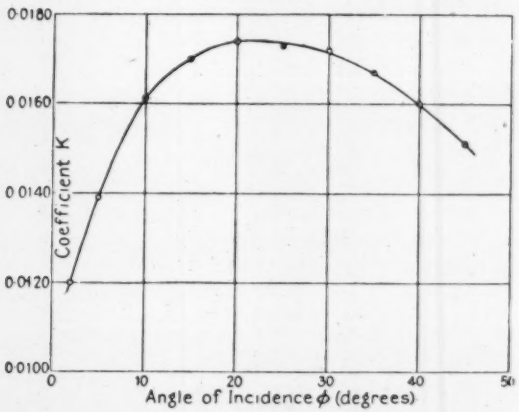


Fig. 36.

* Most of the material in this section has been taken from the following papers written by the author: "A Low-Speed Vane Anemometer," *Journal Scientific Instruments*, January, 1926, "The Theory of the Vane Anemometer," *Phil. Mag.*, 1926, ii., p. 881.

with the normal to the wind direction through O, and that the magnitude of the force F is given by the equation,

$$F = K\rho V^2 S\alpha, \quad . \quad . \quad . \quad . \quad (1)$$

where K is a numerical coefficient whose value depends upon α. Usually it will be found more convenient to resolve the

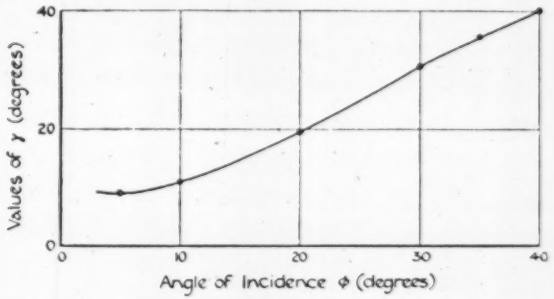


FIG. 37.

force F into two components L and D respectively perpendicular to and along the wind direction. Thus

$$\left.\begin{aligned} L &= K\rho V^2 S\alpha \cos\gamma \\ D &= K\rho V^2 S\alpha \sin\gamma \end{aligned}\right\} \quad . \quad . \quad . \quad (2)$$

Values of K at different angles of incidence have been obtained experimentally by the author for typical anemometer blades, and are given in the following table and in Fig. 36. Values of γ deduced from G. Eiffel's experimental results * for small square flat plates are shown in the same table and are plotted in Fig. 37.

TABLE VII

Angle of Incidence Degrees.	K	γ Degrees.
5	0·0123	9·0
10	0·0139	11·0
20	0·0174	19·5
30	0·0172	30·7
35	0·0167	35·8
40	0·0160	40·3
45	0·0151	—

Application of Flat Plate Characteristics to the Anemometer.—We may now consider the aerodynamic characteristics of flat plates in relation to their application to the vane anemometer. The following notation will be used :—

* See *La Resistance de l'Air et l'Aviation*, p. 134.

F = resultant wind force on one blade,
T = frictional resisting torque,
Q = wind torque on blades,
V = wind velocity,
v = linear tangential velocity of centre of pressure of blade,
$\overline{V} = \sqrt{V^2 + v^2}$ = velocity of wind relative to blade,
K = wind force coefficient (see above),
ρ = air density = $\frac{\text{weight per unit volume}}{g}$,
θ = inclination of blade (when at rest) to wind direction,
ϕ = inclination of blade to relative wind = effective incidence of blade,
γ = inclination of resultant wind force on blade to perpendicular to direction of relative wind,
n = rotational speed of blades,
N = rotational speed of pointer,
C = gearing constant, such that $N = Cv$,
A = area of one blade,
D = diameter over blade tips,
m = number of blades,
r = distance of centre of pressure of blades from axis of rotation,
I = total moment of inertia of all blades about axis of rotation,
g = acceleration due to gravity.

A. H. Shafer has been recently appointed Manager of The Foxboro Company's Pittsburgh Office, replacing H. S. Gray who is now in charge of office routine at the home plant.

A Porcelain Insulator, a Recorder Chart or—a Complete Pyrometer Control Installation can be furnished by

CLAUD S. GORDON COMPANY

"THE HOUSE OF SERVICE"

Established 1914

CHICAGO CLEVELAND INDIANAPOLIS

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NEW INSTRUMENTS

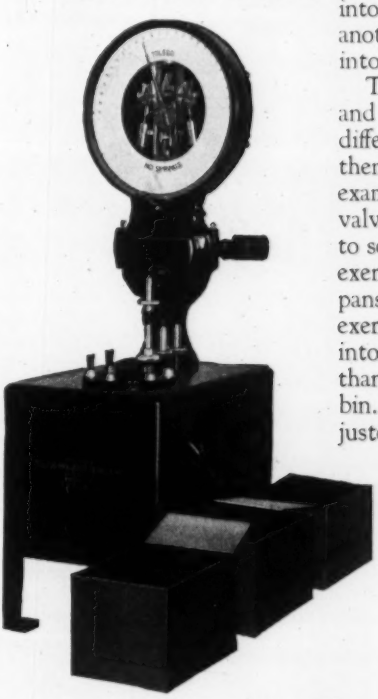
Recently Developed by Instrument Manufacturers

Write Information Section, Instruments Publishing Co., Pittsburgh, Pa., for additional Information.

New Automatic Compression Spring Testing and Selecting Auto Gage

(Toledo Precision Devices, Inc.)

THIS new Auto Gage will prove of value to all manufacturers who seek uniformity in compression coil springs. As they pass through the Auto Gage each spring is compressed to a predetermined length, and the expansive force exerted by each spring thus placed under compression, is automatically indicated in pounds on a large dial. The springs are then discharged through a swinging chute, those of the proper stiffness dropping into one bin, those which are too stiff into another bin, and those not stiff enough into a third bin.



The Auto Gage may be set to compress and test springs of different lengths, and different degrees of stiffness, and to sort them within any desired tolerance. For example: it may be adjusted to compress valve springs to a length of 2½ inches, and to select and drop into one bin all springs exerting between 35 and 40 lbs. of expansive force when so compressed. Those exerting less than 35 lbs. being discharged into a second bin, and those exerting more than 40 lbs. being discharged into a third bin. The machine can be readily adjusted to make the tolerance as close or as liberal as desired.

The springs are dropped into sockets in a disk, which is intermittently rotated, carrying each spring beneath a plunger which descends and compresses the spring to a predetermined length. The pointer on the dial automatically indicates the force exerted by the spring when compressed, and the chute swings to position to discharge the spring into the proper bin.

Never before has there been a device designed to accomplish the results which this new Auto Gage gives. Not only is it accurate in its operation, but it is also automatic. The Toledo Spring Testing Auto Gage can be set to select springs with a tolerance as low as four ounces.

Rectifier Type Instruments

*W. N. Goodwin, Jr.**

General. This type of instrument is used principally for the purpose of measuring alternating currents of such small magnitude that they cannot be measured readily by means of the ordinary types of A. C. instruments such as thermal, soft iron and electrodynamometer types.

It is also useful where accuracy is not of so much importance as ruggedness and ability to withstand heavy overloads without damage.

Construction. It consists of a sensitive direct current permanent magnet movable coil instrument used in connection with a rectifier made of 4 sets of copper oxide discs arranged in the 4 arms of a Wheatstone bridge circuit, the instrument being connected as the usual galvanometer in the bridge circuit. The copper oxide discs are so arranged that both halves of the A. C. wave pass through the instrument in the same direction as shown in Fig. 1.

Principle of Operation. As stated above, each half of the A. C. wave is rectified and passes through the instrument in the same direction, and since the instrument is a permanent magnet movable coil type the indications are proportional to the simple average value of the wave, and not to the squares of instantaneous values as is the case in A. C. instruments of the ordinary type, which are universally calibrated in root mean square values (R.M.S.).

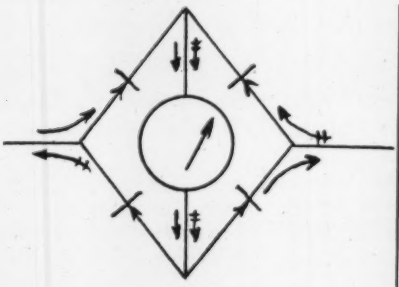


Fig. 1

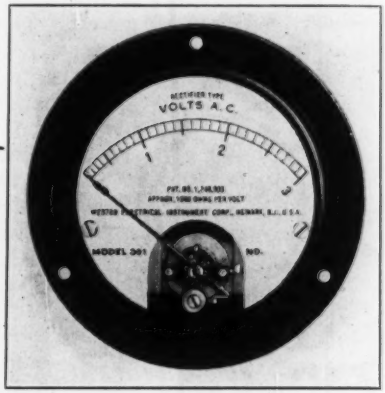


Fig. 2. (at right

As it is very desirable, however, to measure alternating currents in the conventiona R.M.S. values, the rectifier instruments are calibrated by using as alternating current having a pure sine wave shape, and the scale figured in R.M.S. values.

It is obvious, therefore, that if the alternating current to be measured has any other shape than sinusoidal, errors will result, since the relation existing between R.M.S. and average values for sine waves in general is quite different from the corresponding relation for other wave shapes. This and other sources of error will be considered below.

Accuracy The principal sources of error in the rectifier type instrument are temperature, frequency, wave form, and the fact that the resistance of the rectifier varies with the amount of current passing through the discs. In addition to these, there may be permanent changes which may take place in time, but which experience thus far has not fully established.

Temperature Errors. Errors due to temperature changes depend upon the resistance of the circuit and upon the current passing through the rectifier. In voltmeters this is equivalent to stating that temperature errors depend upon the range in volts and upon the resistance in ohms per volt.

Temperature errors are the result of 2 changes which occur in copper oxide. When the temperature increases the rectifying property, diminishes, or stated technically, the rectification ratio is reduced, and at the same time the resistance of the rectifier is reduced. These 2 effects are in opposite directions upon the instrument indications, and fortunately, in most practical instances, actually neutralize each other near room temperature.

For voltmeters of the usual resistance of 1000 or 2000 ohms per volt, and for ranges from 1.5 to 20 volts, if used between temperatures of 18°C. and 35°C. (64°F. to 95°F.), errors due to temperature alone will probably not exceed 2%. For ranges above 20 volts, and for

*Chief Engineer, Weston Electrical Instrument Corporation.

milliammeters, the temperature range may be 18°C. to 30°C. (64°F. to 86°F.) without exceeding an error of 2%. As the temperature effects increase rapidly for temperatures outside the above limits, it is very desirable to make all measurements within the temperatures stated. These errors are of course in addition to the usual scale calibration and adjustment errors.

Frequency Errors. Up to 35,000 cycles per second the instrument indications decrease at a substantially uniform rate of approximately ½ of 1% for each 1000 cycle increase in frequency. For example, at 4000 cycles per second the instrument would indicate 4 x ½ = 2% low.

Errors Due to Change in Current Density. The resistance of a given rectifier depends upon the magnitude of the current passing through it, or in other words, upon the voltage drop across it. The resistance increases as the current density or voltage drop decreases. An instrument, therefore, has a lower resistance for full scale current or voltage than at any lower part of the scale.

In voltmeters, this resistance change is calibrated into the scale and, therefore, results in no error as far as the instrument indications are concerned. However, since the resistance changes, the instrument acts as a varying load on the circuit tested and if the circuit has a relatively high resistance, the instrument resistance variations may affect the terminal voltage in the circuit being tested, although the instrument will correctly measure the actual voltage applied to its binding posts.

When a rectifier type milliammeter is connected in a circuit, it affects the circuit conditions on account of its added resistance like any other type of instrument except that the effect depends upon the magnitude of the current passing, and the error will depend upon the total resistance of the circuit including the instrument, and also upon the current, that is, upon the scale indication.

For example, the rectifier usually used in a 500 microampere instrument of the 3½" size (Model 301) will have a resistance of approximately 710 ohms including the D. C. instrument at full scale, 500 microamperes, and 1540 ohms at 0.3 scale or 150 microamperes. (See Fig. 2.)

If the circuit resistance is relatively very high then this change will result in negligible errors. If, however, the circuit under test has a low resistance, say 1000 ohms, then the total circuit resistance for a current of 500 microamperes would be 1000+710=1710 ohms and the current indicated will be 1000/1710 x 100=58.8% of that which would have resulted if the instrument had not been in circuit. For a current of 150 microamperes, the circuit resistance would be 1000+1540=2540 ohms and the current indicated is, therefore, 1000/2540x100=39.4% of that which have resulted had the instrument not been in circuit.

It must be remembered, however, that the instrument correctly indicates the actual current passing at any time, but the magnitude of this current depends partly upon the presence of the instrument in the circuit, as in the case of any other type of milliammeters.

Another effect produced by the varying resistance of the rectifier is to slightly distort the wave form of the current in the circuit, which may cause a slight error. As a guide in estimating the effects of the varying resis ances of the rectifier type instrument, the following tabulated values are given for Model 301 instruments.

Range	Approx. Res. at Full Scale Ohms	Approx. Res. at 0.3 Scale Ohms
500 Microamperes	710	1540
1 Milliampere	440	930
2 Milliamperes	290	590
5 Milliamperes	180	325

Wave Form Errors. As stated above, since a D. C. instrument is used, the rectifier type instrument actually measures the average values of the rectified wave. The conventional manner of designating alternating currents or voltages is to state them in terms of their root mean square (R.M.S.) or effective values, for the reason that the ordinary A. C. instruments indicates these values, and power is proportional to these values.

For this reason, rectifier instruments are calibrated with currents or voltages having a sinusoidal wave form and the scale is figured in R.M.S. values. It is obvious, therefore, that the instrument indicates correctly only if the currents or voltages measured have sine wave shapes. For other wave shapes errors will result, of varying magnitudes depending upon the variation from the true sine wave shape.

As a simple illustration to show the possible magnitude of errors due to wave form, consider the rectangular wave shown in Fig. 3. This shape of wave is that which would be produced by commutating the voltage of a battery or other D. C. source.

From simple inspection it is seen that the maximum, R.M.S. and average values of the rectified wave are all equal and equal to v.

If, however, a voltage of this wave form is measured on the rectifier instrument it will indicate the R.M.S. value of a pure sine wave which has the same average value v that the

actual wave has. Now it is well known that the R.M.S. value of a sine wave, whose average value is v, is 1.11 v so that the instrument will indicate about 11% too high for this wave form.

Any wave form can be expressed as the sum of a series of pure sine waves consisting of a fundamental and of harmonics, the harmonics having frequencies of 2, 3, 4, 5, etc. times the fundamental frequencies. Pure A. C. waves can consist of the odd harmonics only, 3, 5, 7, etc. For example, the above rectangular wave consists of a fundamental wave of a magnitude of say 100%, and the following series of harmonics, 33⅓% third, 20% fifth, 1· %
seventh, etc.

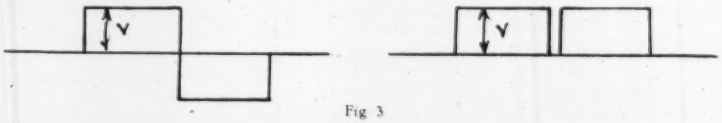


Fig 3

The errors produced by distorted wave shapes depend not only upon the magnitude of the harmonic, but upon its phase relation. The effective or R.M.S. value of any distorted wave is equal to the square root of the sum of the squares of the R.M.S. values of the fundamental and each harmonic, that is

$$V = \sqrt{v_1^2 + v_3^2 + v_5^2 + \ldots}$$

whereas the average value of a rectified distorted wave is the average value of the fundamental plus or minus the value of each harmonic averaged over a half fundamental cycle, depending upon the phase.

The following tabulated values give some idea as to the magnitude of errors produced in measuring distorted wave shapes.

Harmonic	Magnitude in Percent of Fundamental	Phase Displacement	Ratio of Indication to True R.M.S. Value
3rd	10	180	0.961
3rd	20	180	0.927
3rd	30	180	0.862
3rd	33⅓	180	0.840
3rd	33⅓	0	1.052
5th	10	180	0.970
5th	20	180	0.943
5th	30	180	0.900
3rd & 5th	30 & 30	0 & 0	1.063
3rd & 5th	30 & 30	0 & 180	0.952
3rd & 5th	30 & 30	180 & 0	0.877
3rd & 5th	30 & 30	180 & 180	0.775

It is quite evident from the above discussion that among the errors which may be encountered in the use of rectifier type instruments, those resulting from wave form are the most serious.

There is also the possibility that a permanent change may take place in time in the copper oxide itself, but observations to date indicate that such changes are small, probably of the order of 1% or less.

In general it may be stated that if the instrument is used on wave forms closely approximating sine waves, such as found on lighting circuits, and if used at room temperature, the indications may be relied upon to within about 5% of full scale value. Errors due to frequency can be corrected.

When writing to the above compan · please mention INSTRUMENTS

Pittsburgh Truck Recorder

(Pittsburgh Taximeter Company)

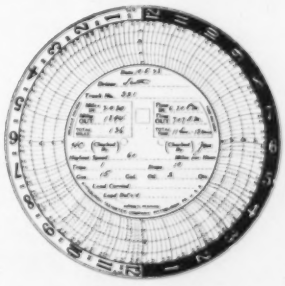
THE Pittsburgh Truck Recorder, a sturdy and rugged instrument, produces a record on a 7" diameter chart, for a 24 hour workday, and shows all the movements of the truck or vehicle.

This instrument takes all guessing out of the picture. Instead of taking for granted the performance of trucks, the only conclusive way to tell whether the maximum efficiency together with the lowest upkeep on individual or a fleet of trucks is obtained, is to have a daily chart record. The chart records of this recorder are effective, simple and entirely reliable, and thereby eliminate any controversy arising from self-interest, faulty memory or incorrect testimony of employees or others.

The Chart Record as produced on this chart, is a punched record so as to prevent any possible tampering with same. Also, if it is so desired this recorder can give a chart record in duplicate or triplicate. A triplicate chart record provides one copy for the garage, one for the district office and a copy for the main office.

Some of the facts that can be read from the chart record are as follows:—

1. Indication that trips have been run as per schedule.
2. To determine schedules.
3. Highest Speed: Miles per Hour.
4. Average Speed: Miles per Hour.
5. Time and Duration of Stops.
6. Time and Duration of Trips.
7. Total Operating Time.
8. Total Idle Time.
9. Total Actual Running Time.
10. Time Truck is Taken out without Permission.
11. Mileage Used without Permission.
12. Total Miles Traveled.



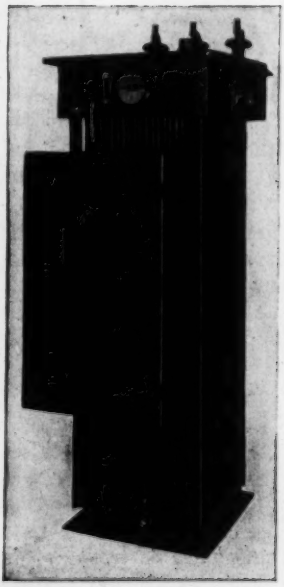
The instrument also indicates to the driver, the accurate vehicle speed and the correct time of day. The mileage record shows the owner that the driver has not wasted gas and oil and that he is trying to reduce expenses.

The Pittsburgh Truck Recorder is mounted on the dashboard of the vehicle and is driven by means of a transmission drive, the same as the speedometer drive. In most cases, it is only necessary to disconnect the cable from the present speedometer and connect same to the recorder. This type of installation is very durable and will give dependable service the year around.

Here is a specific and typical example one record covering one working day for one vehicle which is shown on the chart below:—

Perhaps the truck is scheduled to start work at seven every morning. (Do they?) Then, how long does it take to put on the first load? Maybe half an hour some days, but an hour other days. Between ten and eleven someone calls to know where that "promised early delivery" has gone. (It left the shipping platform on time. Something must be wrong somewhere.) Just about that time the traffice manager learns of a summons to traffic court for charges of speeding against one of his drivers. (Is he

guilty?) Then, too, to get the monthly gasoline and tire expenditure. Why do the trucks use so much gas and are so hard on tires? (How far do they travel a day?)



Front view of type S Regulator, its neatness and compactness.

Oil Immersed Induction Regulators

THE demand for smaller, more compact induction feeder voltage regulators, led to the design of this totally submerged regulator. It may be used either indoors or outdoors. Desirable features embodied in this regulator includes reduced height, oil immersed motor and operating mechanism and quiet operation.

This regulator has been developed by the Westinghouse Electric and Manufacturing Company to supplement the well known line of Type "C" Regulators.

Protective System of 3-Wire Control

THE Minneapolis-Honeywell Regulator Company has developed a safety system of 3 wire control, designated by them as "Series 10," which they utilize in some of their temperature and pressure controllers. Basically, it involves the making at the temperature or pressure controller of a circuit to start the load, such as the motor operated valve of a fuel oil or gas burner, and the breaking of the same circuit to stop it. Hence any failure of wiring —breakage, poor connections, etc., through this closed circuit wiring instantly shuts off the burner. An adjustable lag provision is inherent in the instrument design with the result that vibrations will not cause rapid starting and stopping of the burner. Rather, the locking action of the circuit makes relay operation positive. The fact that the actuated blade of the instrument is unrestricted in one direction of travel accounts for greater constancy and sensitivity than the standard 3 wire controllers where a separate strain release for both movements must be employed.

By referring to Fig. 1 it will be noted that one side of the secondary of the transformer which furnishes low voltage to this control circuit is connected to the white (high) contact post of the temperature controller, illustrated here as a simple thermostat, and the other side is connected to the relay coil. When the temperature falls sufficiently to close first the blue (low) and then the white (high) thermostat contacts, the circuit is completed from the white contact of the thermostat, to the secondary of transformer, to the relay coil and back to the blue thermostat contact. The relay coil, thus energized, will pull in the armature and close its contacts, thereby completing the red holding circuit through contact No. 1 of the relay. The circuit then holding the relay in place is from the white contact of the thermostat, through the secondary of the transformer, the relay coil, to No. 1 red contact of the relay back to the red (common) post of the thermostat.

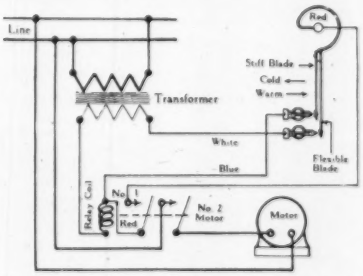


Fig. 1—Showing Position of Relay and Thermostatic Controller Contacts when the Motor is Idle

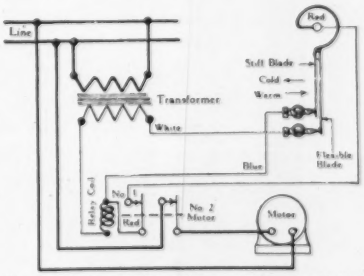


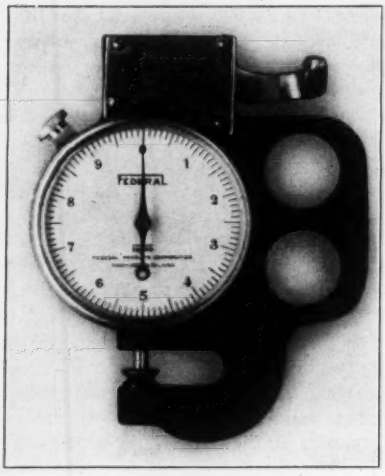
Fig. 2—Showing Position of Relay and Thermostatic Controller when the Motor is Operating

Upon closing the relay contacts No. 2 in the motor circuit is made and the burner starts.

As the temperature rises, the blue contact will be broken—but the motor will not stop because relay is being held in by the red holding circuit. A lag adjustment is made in the thermostat mechanism by virtue of the flexible blade which retards the breaking of the white upon temperature change. When this contact of the thermostat is broken, opening the circuit to the coil, the relay drops out, hence disconnecting the load.

New Model Dial Thickness Gage

(Federal Products Corp.)



MODEL 390 is similar to a gage already available, which was graduated in 0.001 in. This gage is calibrated in 0.0001. The graduations are the same distance apart as the graduations equalling 0.001 on the ordinary dial indicator. The tension spring of the gage can be altered to suit various needs. Anvils are hardened and ground, either flat or ball pointed. The spindle is raised by pressing down on the small lever at the top.

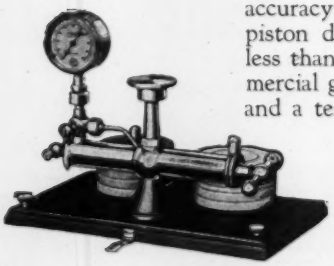
The field for this gage is for measuring any type of flat material within the range of the gage such as felt, sheet metal, leather, fabrics, cardboard, rubber, celluloid, battery separators, fibre, webbing, and glass.

American Dead Weight Pressure Gage Tester

(Consolidated Ashcroft Hancock Company Inc.)

THIS instrument is a simple and compact mechanism for the testing of all pressure gages up to 1000 lbs.

Since the testing is made by the use of dead weights in 5 lb. units, this type of tester is very accurate. The only inaccuracy possible is due to the tolerances in the piston diameter and weights. This amounts to less than 0.1% of the actual reading while a commercial gage is accurate to about 1% of the range and a test gage 0.5% of the range. The lowest pressure which can be tested is that corresponding to the weight of the piston. The tester for pressures to 200 lbs., 300 lbs. and 500 lbs. has a $\frac{1}{8}$" piston which weighs 5 lbs. The tester for 800 lbs. and 1000 lbs. has a piston $\frac{1}{16}$" diameter and weighs 10 lbs.



The weights are die cast. They are stacked on posts on the same base as the tester, for convenience in using, and to prevent their being mislaid. This also makes for a compact unit. The tester is made of brass, nickel-plated and is an integral part of the cast iron base. The cover is made of sheet steel with a crystallized finish, and fits over the complete tester and may be locked to the base. All the necessary tools are suplied in a convenient, fabrikoid carrying case. They consist of two wrenches, a screw driver, pliers, gauge pointer remover, gauge pointer setter, a spirit level and the necessary connection nipples.

Three New Oscillographs

THREE new permanet-magnet oscillographs, for studying a multitude of phenomena that vary rapidly with time, have been announced by the General Electric Company. They include a 6 element, general-purpose oscillograph, a 2 element, portable type, and a continuous-viewing one.

The constantly increasing use of oscillographs by electrical engineers engaged in the design and application of electrical machinery is now extending to the larger group of electrical engineers who use and operate the machinery, to mechanical engineers in their study of vibrations, pressures and performance sequences, and to development engineers for "visualizing" the new and unknown in their many projected schemes. The medical profession uses oscillographs in the study of heart beats; and, in schools and colleges, oscillographs make clear to the students things which would otherwise be uncertain and intangible. This extensive use has resulted from a more general realization of the utility of these instruments and from the great advances in design which have made possible their wide-spread use.

Such a use of oscillographs is not satisfied by a single design of instrument. For the lower frequencies, such as those up to 2000 cycles second, the magnetic type of oscillograph galvanometer is used; for higher frequencies the cathode-ray beam, having no inertia, is used to trace the record on the photographic film. The new instruments are of the permanent-magnet type.

General-purpose Six-element Oscillograph. The new general-purpose 6 element oscillograph is of compact design and is supplied with a protective carrying case for portability. A seventh or timing vibrator makes it a seven-element instrument for many purposes. The galvanometer circuit switches and protective fuses are located on the top, and the circuit resistors are easily available on the sides. The long-life incandescent lamp and the film-driving motor operate from a 6 volt storage battery or an alternating-current power source.

The film holders are of the magazine type providing for several exposures, or the continuous-drive type providing for long single exposures, as up to 20-foot films. The automatic shutter tripping mechanism, providing for proper time sequence of operating the shutter, is a new and exclusive feature. The walnut case measures 26″ x 12″ x 9″, and the main unit weighs 70 lbs. complete.

The instrument is rated for operation at 250 volts, withstanding a high-potential of 10,000 volts at 60 cycles for one minute between galvanometers and between galvanometers and ground. External resistors for operation up to 3,000 volts are available.

If the recording of power is desired, a 3 element watt-galvanometer which may be connected to record the summation of the instantaneous values of power in the phase of a 3 wire, or 3 phase 4 wire circuit. Watt galvanometers, interchangeable with the current and voltage galvanometers, are also available. The leads from these elements connect to the station current and potential transformers through external rheostats suitably mounted.

Automatic operation for use on transmission lines is provided by the use of proper auxiliary relays. These provide for starting the film-driving motor from rest, and bringing the lamp up to required brilliancy, so that the record is obtained in about 10 cycles (of a 60-cycle wave) after the occurrence of a disturbance.

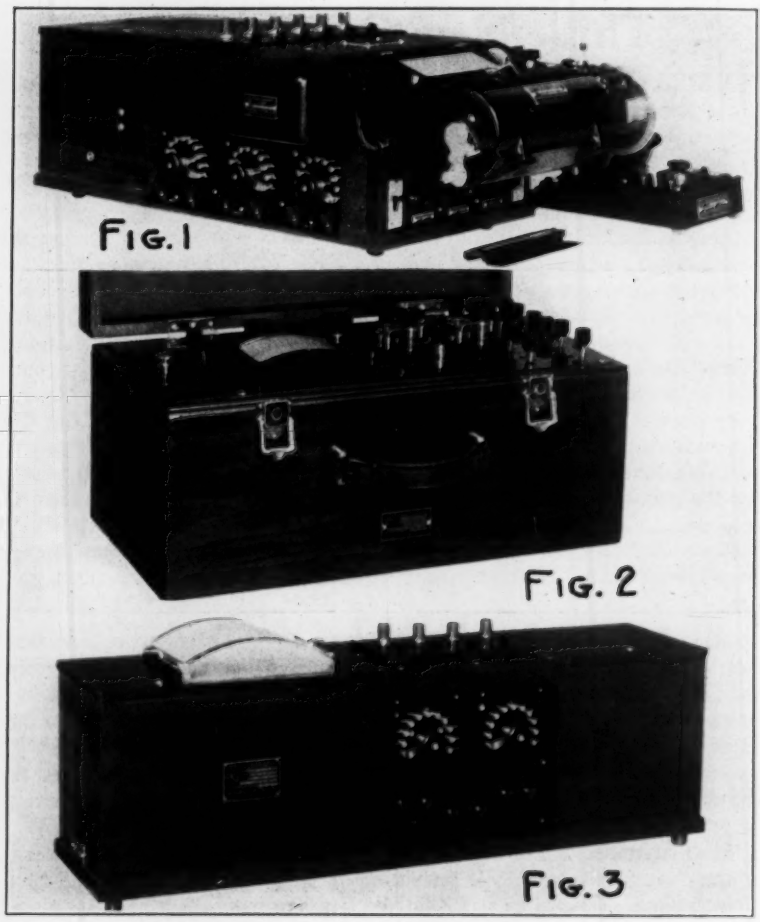


Fig. 1. Six-element, General-purpose Oscillograph, Type PM-10.
Fig. 2. Two-element, Portable Oscillograph, Type PM-12.
Fig. 3. Continuous-viewing Oscillograph, Type PM-11.

Portable Two-element Oscillograph. For viewing the wave form of the circuit current and voltage just as one uses an ammeter or a voltmeter, the portable 2 element oscillograph is provided with 2 galvanometers, one for current and one for voltage. It is entirely self-contained, and weighs only 27 lbs. The record is observed on a screen, or may be presented to the view of an audience, and a camera for photographing the record is provided.

The principal application of this oscillograph is for viewing the wave shapes of recurrent phenomena. A transient may be seen if it is not of too short duration, and the portion corresponding to a single movement of the light beams across the film may be recorded.

Continuous-viewing Oscillograph. The continuous-viewing 2 element oscillograph will show wave forms on a screen, is designed for continuous operation, and can be used by operators not particularly skilled in instrument use. A self-starting single-phase synchronous motor, operating from

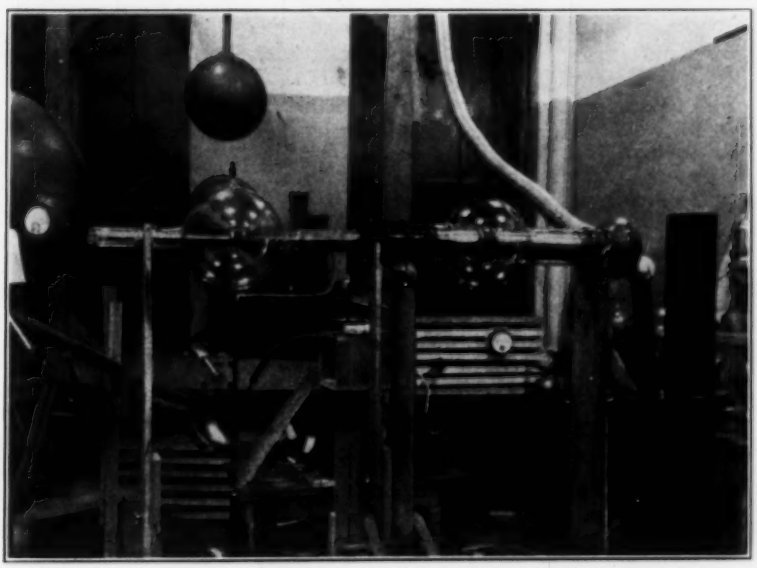
a 110-120 volt lighting circuit, drives the oscillating mirror that projects the light beam on the screen. These waves will appear stationary on the screen if the alternating-current source used to operate the synchronous motor is the same as that connected to the galvanometers. The waves may be traced if desired or may be photographed if sensitized paper is placed over the screen and the oscillograph is used in a dark room. This gives a record of wave shapes and phase relations which is inexpensive and yet is satisfactory for analysis.

Half Million Volt X-Rays

X-rays at 500,000 volts, more than twice as high a voltage as is being used in today's most powerful therapy tubes, have been attained by Dr. W. D. Coolidge, associate director of the General Electric research laboratory at Schenectady. Such a decided increase in voltage, and hence increase in penetrating power of the rays, was made possible by a system of "cascading" the tube, an arrangement devised by Dr. Coolidge in his work with high-voltage cathode-ray tubes.

The announcement of the new tube was made at the convention of The American Roentgen Ray Society, at West Baden Springs, Ind., on September 24, when the Caldwell lecture was given by Dr. Coolidge. In his talk, wherein he reviewed the development of modern X-ray generating apparatus Dr. Coolidge not only announced that X-rays at a half-million volts had been attained in the Schenectady laboratory, but he also stated that another X-ray tube is now being developed there to operate at 900,000 volts.

The 500,000-volt X-ray tube, Dr. Coolidge said, is built in 2 sections. In his previous work in cathode-ray tube development it was found that tubes can be built for very high voltages by the use of a cascade (or sectional) system, and that by this method there appears to be no limit to the voltage which can be used. The target replaces the "window" of the cathode-ray



tube so that, instead of cathode rays being emitted by the tube through such a "window," X-rays of exceedingly high penetrability are generated by the impact of the electrons (or cathode rays) on the target.

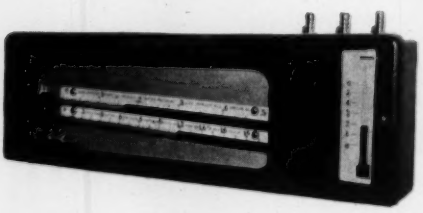
Earlier attempts in the Schenectady laboratory to build experimental X-ray and cathode-ray tubes for voltages appreciably in excess of 250,000 ran into difficulties due to a "cold cathode" effect, whereby current flowed through the tube even when the cathode filament was not heated. Continued investigations showed that this limitation could be removed by dividing the voltage applied to the tube between different pairs of tubular electrodes. By thus dividing the tube into sections, each of which may be good for as much as 300,000 volts, a three-section cathode-ray tube for 900,000 volts was constructed some years ago. Such a cascade or multi-sectional system, Dr. Coolidge, found, promises to permit the building of vacuum discharge tubes for as high voltage as can be generated—and voltages of millions are being produced in the Pittsfield laboratory of the General Electric Company. The use of the cascade tube applies equally well to X-ray and cathode-ray tubes, since the latter may be converted into the former by the addition of a suitable target.

The highest-voltage Coolidge X-ray tubes used commercially at the present time are of 200,000 volts peak capacity, and are of 2 types—water-cooled and air-cooled. Both are adaptable for X-ray therapy. The air-cooled type has been used to considerable advantage in industrial applications of X-rays, since the high voltage gives the necessary penetration required for examining the heavier metal objects. Industrially, higher voltages would permit radiography of thicker metals, and shorten times of exposures.

Compact Multiple Manometer

THE combination instrument shown in the accompanying illustration is designed to overcome the difficulty of mounting pressure and flow instruments of the manometer type in a neat and compact manner on control panels. It is manufactured by the Meriam Co.

This neat appearance is sometimes difficult to obtain with the ordinary types of draft gages where widely differing pressures must be indicated, because the principle of the gage depends upon the length of the tube and the liquid used. As a result, compactness may have to be sacrificed to obtain the basic accuracy which is the characteristic of the manometer principle.



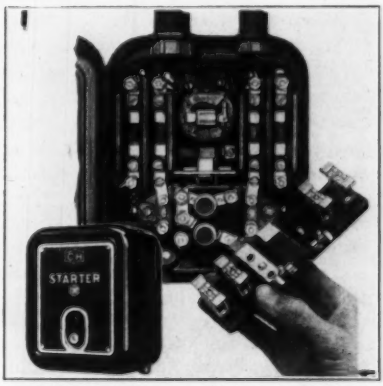
The particular instrument shown is one of several made for panel mounting in the plant of the Gulf Production Co., Pittsburgh, Pa. for the measurement of forced draft furnace and stack conditions on pulverized coal fired boilers. There are 3 draft gages in the combination instrument. One of these measures up to 6 inch wager gage pressure, and is connected to the forced draft at the fire-box. The second and third are of the inclined tube type and measure the draft at the fire arch of the boiler

and at the stack outlet respectively. They have a range of only one inch water gage. In order to get as large a reading as possible, red oil is used in the inclined manometers, while to reduce the length of tube necessary for measuring the 6 inch force draft pressure, the liquid used in the vertical manometer is a special preparation having the unusual specific gravity of 2.97—that is, somewhat heavier than that of hard drawn aluminum. This high specific gravity permits the length of the tube to be reduced to a little over 2 inches, and thus the entire apparatus can be easily contained in the standard 17" x 5¼" polished aluminum case used for the regular Meriam draft gages. The fill-plugs are placed conveniently at the top of the instrument.

New Magnetic Contactor Used On Cutler-Hammer A. C. Motor Control

(Cutler-Hammer, Inc.)

THIS new contactor provides many features which are of interest. The contacts are of heavy coin-silver which retains its current carrying capacity even if oxidized and always makes a good contact with little temperature rise. The "Twin Break" principle reduces the arc voltage by half, and Thermoplax arc pockets, by reducing the air content around the contacts, actually prevents the formation of a destructive arc. These arc pockets also act as a shield so that wires which are run along the side of the contactor cannot interfere with its operation.



A magnetic latch has been added to prevent accidental closure of the contacts if the starter is accidentally bumped or tilted—the latch must be drawn aside by the operating magnet before the contacts can close. This is an important feature, especially if the starter is mounted on moving machinery. A new hinge structure facilitates removing and replacing the contact board and insures correct replacing of the board before the starter can operate.

These new contactors are made in 3 and 4 pole types. The maximum rating for 2 or 3 phase are: 3 H. P., 110 volts; 5 H. P., 220 volts and 7½ H. P. 440 or 550 volts. The illustration is of the Bul. 9586 across-the-line type starter which is using this new contactor. The contact board is removed to show the silver, butt type contacts.

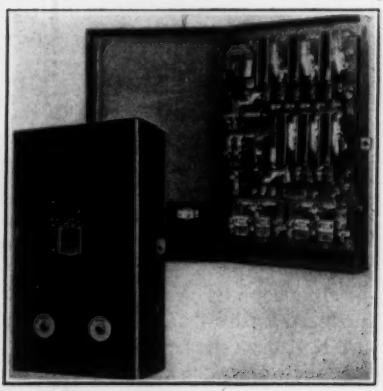
A New Line Drop Compensator

A NEW line drop compensator that has no contacts nor taps has been developed by the Westinghouse Electric and Manufacturing Company. Two miniature induction regulators from the main part of the compensator are horizontally mounted in the lower part of the case. Above the regulators are fastened the resistance for the primary relay compounding coils and the resistance which serves both as the primary relay series resistance and the compensating resistance.

Losses are kept at a minimum in this compensator by combining the primary relay resistor with the resistance element. Two scales are provided, one for 8.7 amperes and the other for 5 amperes.

Automatic Controller for A. C. Multi Speed Motors

CUTLER-HAMMER, Inc. announce the development of a new automatic controller for two speed, consequent pole type (reconnected) squirrel cage motors. This controller, known as Bulletin 9739, functions to start the motor and to change its speed by reconnecting the motor windings. It provides thermal overload protection at both motor speeds and low voltage protection. A separate pushbutton master switch with "stop," "low," and "high" buttons provides three-wire remote control.



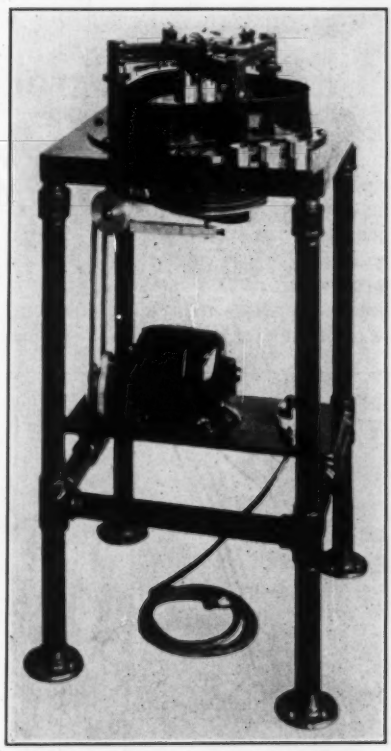
These new controllers are furnished for constant horsepower, constant torque, or variable torque motors. A sequence compelling feature can be furnished which makes it necessary to always start the motor on low speed before bringing it up to high speed.

The entire mechanism is mounted on a single slate panel, which is easily removed from the case by removing four screws. The split type enclosing case provides easy access to all parts when the cover is opened. Conduit knockout holes are provided in the top, bottom and sides of the case.

Automatic Polishing Machine

(Chemical Rubber Co.)

THIS automatic Polishing Machine was designed in the laboratory of the Bureau of Standards after careful, accurate analyses of existing operating methods and equipment. The result is an automatic polishing machine which eliminates the personal equation inevitably arising in hand polishing. It automatically produces a plane surface with a high quality polish. The machine consists essentially of a polishing disc mounted horizontally on a duraluminum casting which has been heat treated. This casting is attached rigidly to a cast iron table to prevent any possibility of distortion. The polishing disc is belt driven by means of a ¼ h. p. motor and rotates at 400 r. p. m.



Passing vertically through the shaft carrying the polishing disc is a second spindle to which is attached an eccentric gear. This eccentric gear drives the specimen holders, of which there are 3 in such a way that the specimen is slowly moved back and forth along the radius of the turning disc.

At the same time the specimen is slowly rotated so that the direction in which it is polished is continually changed. The gear reduction for the rotating of the specimen is accomplished by a train of gears contained in a gear box located directly beneath the main drive pulley. This reduction ratio is 100 to 1 so that the specimen revolves on the polishing disc at 4 r. p. m.

This rotating movement of the specimen prevents pitting and the formation of "comet tails" at inclusions.

In this machine all specimens must be mounted. The specimen holders will accommodate specimens up to 1 inch in diameter and 1 inch high. The ring in which the specimen is mounted fits into a sleeve mounted on an arm. A tension spring holds each arm in contact with the central eccentric gear. One, two, or three specimens can be polished at one time. The arms can also be disengaged while the machine is in operation.

The specimen holder containing the specimen is held positively in the sleeve with just enough clearance so that the weight of the specimen will bring it in contact with the polishing disc. The tolerance, however, is so close that there is no play between the specimen holder and sleeve.

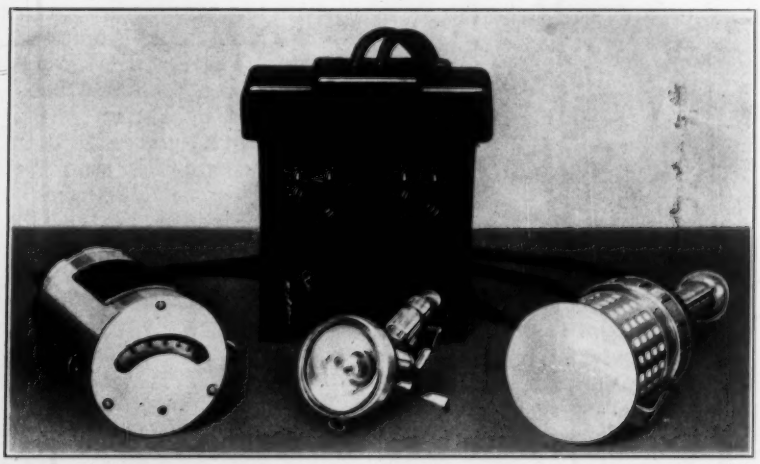
As a general rule, the weight of the mounted specimen is sufficient pressure against the polishing disc. However, additional pressure can be applied by tightening the thumb screw on top of the arm. The pressure is transmitted by means of a spring to a pin which extends through the shaft carrying the specimen holder sleeve and rests on a disc placed on top of the specimen ring.

The main bearing carrying the polishing disc is ball bearing and well protected against abrasives and water. All other bearings on the machine are oilless bearings. The polishing discs, arms carrying the specimen holder sleeves, main drive pulley, and idler pulleys are made of duraluminum. All other parts of the machine are made from stainless steel.

U. C. C. Methane Indicating Detector

THE Union Carbide Sales Company announces the new U. C. C. Methane Indicating Detector for testing air in coal mines. The distinctive features of this instrument are portability, a scale which shows the percentage (from 0.1 to 7.0) of methane present, a detecting head that can be located wherever desired, and exceptional accuracy.

The outfit consists of a detector head, a meter case, a portable storage battery, and a cap lamp. Combustion of a methane and air mixture on the surface of a glowing non-catalytic filament increases its temperature and electrical resistance, thereby actuating a milliammeter needle.

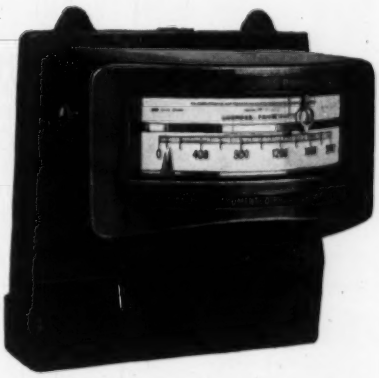


The complete outfit weighs about 12 lbs., is worn strapped to the back and chest, and will operate continuously for 5 hr. without change of battery. The detecting head is attached to a flexible cable and can be placed anywhere a test is to be made. The dial is on top of the meter case which is worn on the chest; the control switches are recessed in the bottom. The cap light furnishes illumination for reading and inspection. The detector is ruggedly built and has safety features which permit changing of filaments even in gaseous areas. A spare battery and all necessary tools are included.

New Indicating Pyrometer Controller

THE new Brown Model 801 Indicating Pyrometer Controller illustrated can be supplied as an automatic control pyrometer, resistance thermometer, tachometer, or CO_2 meter.

Outstanding advantages of this instrument are:



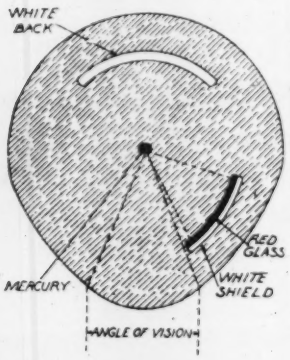
1. Reading observed directly on 6″ scale.
2. Index on scale for setting to exact control point.
3. Control point instantly and easily adjustable.
4. All wiring terminals and motor enclosed. No danger when used in the presence of explosive or inflammable gases.
5. Mercury switches up to 30 amperes capacity, eliminating the necessity of relay equipment. Make and break occurs in sealed glass tube. No danger of spark causing explosion.
6. Suitable for "on and off" or "three position" control through switches, valves, dampers, etc.
7. Available with patented safety device which opens furnace circuit if thermocouple or wiring fails, preventing burning out furnace.
8. High internal resistance, insuring accuracy.
9. Automatic internal compensation eliminating cold junction errors when instrument is supplied as a pyrometer.
10. Simplicity and ruggedness insures minimum of attention.

The control mechanism of Model 801 Indicating Pyrometer Controller combines the basic principle of the Brown Automatic Control Recorder with the new feature of mercury contacts for breaking high currents.

Red-Reading Thermometer Tubing

(Palmer Company)

THERE have been many attempts to produce a contrasting effect, which would aid the user in distinguishing the top of the mercury column. Some of these helps have been more confusing than an aid and eventually were discarded for the regular white-back thermometer glass tube. Many mixtures of chemicals have been concocted which produced a red or other color in the reading column of the tube but none of these ingredients took the place of mercury.

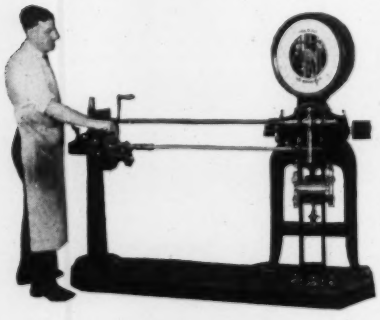


The Palmer "red-reading-mercury" glass colors the mercury column to show a bright red instead of the regular silver-mercury. This is accomplished by means of reflection. Mercury is a natural mirror so that by placing a strip of red or colored glass to the side of the bore or reading column and by having this bore turned to a slant, the red glass is reflected onto the mercury column and when visioned through the lens in front of the tube, only the red color is seen. The mercury is not disturbed or harmed by adding any chemical to change its color and you have the effect of reading a bright red column, with all the valuable properties of pure mercury.

Steering Gear Testing Auto-Check

A STEERING Gear Testing Auto-Check for steering gear assembly has recently been announced by Toledo Precision Devices, Inc.

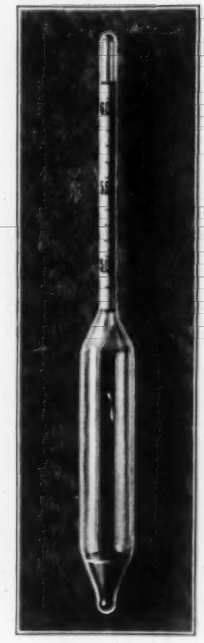
Today automobile manufacturers have various means by which adjustments can be made to take up lost motion due to wear in steering gears. When steering gears are first assemlbed, it is desirable to adjust them so that a definite amount of hand power is required to turn the wheel. The Auto-Check indicates the hand power required and thus enables proper adjustment to be made. In using the new Auto-Check the amount of play of the steering wheel is also readily determined, and the angular movement on each side of center of the drag link arm is indicated.



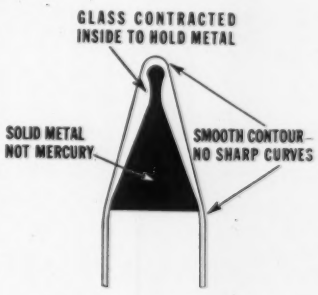
In the operation of the Steering Gear Testing Auto-Check the housing of the worm and sector assembly is first fixed in a quick operating lamping device on the machine. Then the free end of the steering wheel shaft is engaged in a socket connected by an ingenious system of gearing to a force measuring and indicating instrument. When in this position, turning the crank will show how much power is required on the steering wheel to turn the steering gear to any position. Various adjustments may then be made to bring the sector into proper mesh with the worm on the shaft, and the desired resistance to turning, proper wheel play, and correct drag link arm movement may be inspected. This device is so designed that it can be made to fit any type of steering gear.

NU-TYP TAG Hydrometer

(C. J. Tagliabue Mfg. Co.)



SINCE simplicity of construction makes for a more rugged instrument and consequently less liklihood of breakage TAG has designed a hydrometer with a streamline tip. No corners to collect dirt and no chance of it being pulled out of your hand in wiping.



Instead of the usual mercury ballast, a low melting point alloy in a solid piece has been firmly and ingeniously fastened in the bottom of the instrument so that it cannot come loose even when the hydrometer is inverted. Every laboratory will appreciate the use of metal as ballast for hydrometers will break and spilled mercury is dangerous to have around.

The usual high standard of accuracy of TAG Hydrometers is maintained in this new instrument.

The illustration shows graphically the structural features of the Nu-Typ TAG Hydrometer.

Portable Machine for Testing Welds

(Oxweld Acetylene Company)

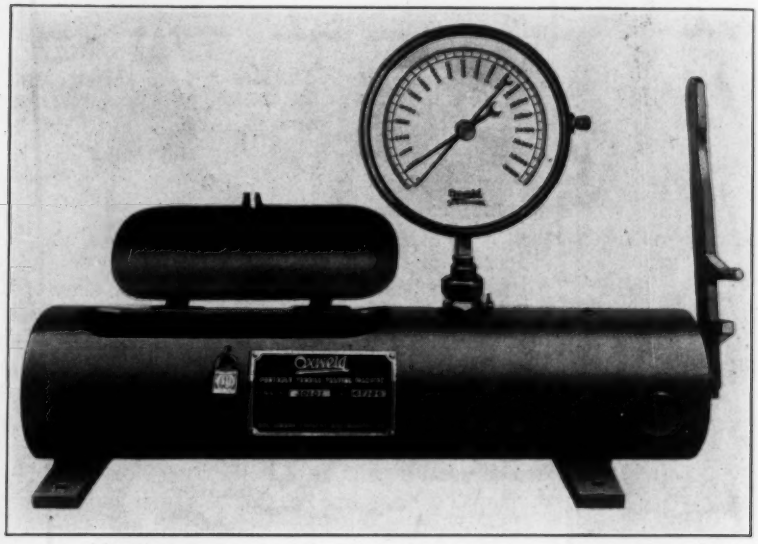
THIS machine was developed in cooperation with Union Carbide and Carbon Research Laboratories, Inc., and, having successfully passed service tests over a period of time, is now being sold as a standard piece of Oxweld equipment.

This machine weighs 165 lbs. and measures 26 in. in overall length and 6¾ in. in maximum diameter. It is a self-contained, totally enclosed unit. When closed for shipment, there are no projections and the machine presents a comparatively smooth cylindrical surface. The accompanying illustration shows how the machine appears when open and ready for making tensile tests.

The machine consists of a tubular compression member with a set of grips in the head and a hydraulic cylinder block in its base. The cylinder block contains a communicating pump and cylinder directly machined into a single block, and the cylinder pressure operates a piston carrying a second set of grips.

The specimen to be tested is placed between the jaws, which have spring grips. The release valve is closed and the pump handle, applied at the end

of the cylinder, is moved back and forth. A set of conical blocks has also been constructed to fit into the machine head in place of the grips so that the standard ½ in. diameter round specimens may be tested if desired. The load is measured directly in lbs. / in. ² by a suitable, calibrated pressure gage actuated by the pressure in the cylinder. The gage is one of the essential parts of the apparatus. When a test is finished, the pressure may be released by a valve and the piston may be returned to its original position by using the pump handle as a lever.



This machine makes it possible to secure a tensile test result immediately after welds are made. This is particularly important in connection with qualification tests for determining welders' ability. It also facilitates making periodic check tests of the operators and in many cases provides a ready means for testing sections cut at random by the inspector from completed work.

The value of this machine in overland and public utility pipe line construction is inestimable not only because periodic tests are required in welding under procedure control, but also because portability of the machine is an important factor. Industrial and power plant piping contractors, and all industries employing welding as a production method will find this machine of service as an aid in maintaining procedure control standards.

EFFECTIVE September 15th, Mr. B. L. Donahue becomes manager of the Buffalo District office of Cutler-Hammer, Inc. Mr. Donahue is widely known in the electrical field, having been connected with the Pittsburgh branch office of C-H for the past 8 years. His wide experience with motor control and other C-H products and their application in industry make him particularly suited to his new position. He is a graduate of Penn State College, class of '20, and holds the degree of B. S. in Electrical Engineering. He is a member of the Association of Iron and Steel Electrical Engineers, and of Sigma Tau Engineering Fraternity.

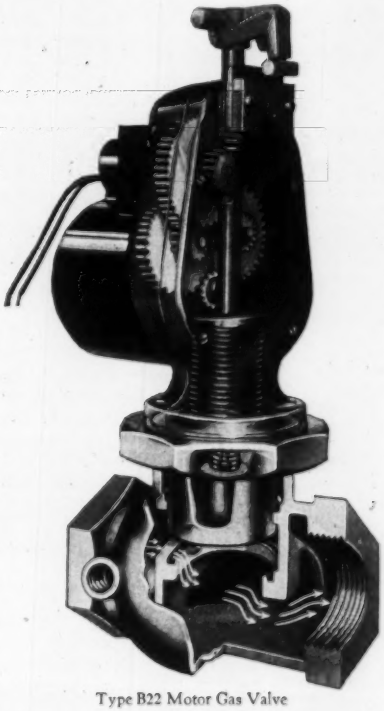
Electric Motor Gas Valves

Automatic Safety Shut-off

(*Minneapolis-Honeywell Regulator Co.*)

THESE compact, electric motor driven, spring actuated shut-off gas valves, dependable and quiet in operation, close automatically in event of power failure.

Operation—When the motor is energized, the rotor drives a reduction train of spur gears causing the plunger to which the valve disc is fastened to rise. As long as the electrical circuit is closed the valve stays open. During this period the motor remains energized and although stalled, will not burn out nor draw much more than normal full load current from the line. The raising of the plunger compresses a monel metal spring. Therefore when the circuit is broken, either in normal operation of the control or through power failure, the spring forces the valve to a positive seat and gives tight shut-off.



Type B22 Motor Gas Valve

Motor—The motor is the standard single phase, shaded pole, squirrel cage induction type and is available for 110 or 220 volts, 25 or 60 cycles A. C. The motor has a surplus of power and will function successfully on voltage fluctuations as great as 15% from normal. This unit is not furnished for direct current.

The bearings require only a few drops of oil annually and the gear trains within the housing are packed with sufficient grease to last indefinitely.

Valve—The valves, sturdy in construction, incorporate carefully designed bodies affording maximum capacity with minimum pressure drop. They are provided with a ¼" pilot opening on both inlet and outlet sides in order to facilitate piping. A double leather diaphragm is used to seal gas from the valve operating mechanism.

Type B22 For 2-wire Control—The 25 watt motor unit is attached to the valve body by means of a clamp nut, which facilitates its removal from the body when working in restricted space. It also permits positioning to any convenient angle.

Valves are available in sizes ¾" to 2", inclusive. They are listed as standard by the Underwriters Laboratories as a final shut-off valve operable against gas pressures of 8 oz. per square inch. Calibration of these resolves the following capacity data, using 520 B. T. U. gas and ¼" pressure drop across the valves.

Size of Valve	Flow
¾"	350 cu. ft. per hour
1"	475 cu. ft. per hour
1¼"	700 cu. ft. per hour
1½"	950 cu. ft. per hour
2"	1300 cu. ft. per hour

Control—The Type B22 Gas Valve is designed for use with 2-wire line voltage control devices. In the event of prolonged current failure the valve may be opened manually by pulling upwards on the latch mechanism which, when engaged, continues the flow of gas to the burners. If the control is calling for heat upon resumption of current the latch automatically releases as the valve opens wide. The valve then will respond to changes in the demands of the controller. If the controller is not calling for heat the latch must be manually tripped in order to recycle.

Type F2210—Many desirable new features have been incorporated in this more powerful and rugged motor operated automatic shut-off gas valve, arranged for use with our "Series 10" low voltage control equipment.

Within its case are compactly housed all moving parts: the 35 watt single phase brushless motor; a reliable transformer and relay; the reduction gear trains; the actuating monel shut-off spring, and other functioning parts.

Low and high voltage terminals are arranged to facilitate connections and are all enclosed within this case. An extra terminal for connecting line voltage blowers, fans or signal lights is provided. The relay contacts for controlling these external loads are rated 10 amperes 110 volts A. C. which is equivalent to that of a 1 H. P. Repulsion Induction or ½ H. P. Split Phase Motor. Also there is provision for electrical connections to a safety pilot circuit.

Types F2210 and V30-1 Motor Gas Valves—The valve can be opened manually and, should electrical energy have failed, it automatically recycles after restoration of power.

The Type F2210 Gas Valve is available in ¼", 1", 1¼", 1½", 2", and 2½" sizes. They are rated as final shut-off valves operable normally against gas pressures of 4 oz. per square inch.

For simultaneous control of the furnace secondary air damper a mechanically operated lever arm extends from the right of the case. The arm is regularly furnished reverse acting with respect to the travel of the valve disc, but can be furnished direct acting on special order.

The ring nut firmly clamping the motor and valve units can be easily removed by releasing on the holding screws and lightly tapping.

Guides on the valve swivel prevent the disc coming down on the seat in a cocked position. The lift is about one half inch, which, with a body designed for minimum restrictions to flow, results in the following capacity data using 520 B. T. U. gas and ½" pressure drop across the valves:

Size of Valve	Flow	Size of Valve	Flow
¾"	500 cu. ft. per hour	1¼"	1100 cu. ft. per hour
1"	610 cu. ft. per hour	2"	1800 cu. ft. per hour
1¼"	925 cu. ft. per hour	2½"	2700 cu. ft. per hour

Control Adaptability—There are numerous applications in the industrial field where these safety shut-off valves, automatically closing on power failure, should not be permitted to open of their own accord upon restoration of power. This can be prevented by wiring a momentary action push button station in their relay circuit.

Often automatic shut-off valves are desired to close the fuel lines to burners of industrial furnaces, in case of a phase failure in the circuits to a polyphase motor which might be used in driving the blower supplying the primary air to the burners under control. Even though the motor unit of this gas valve is a single phase one, we are able through a special wiring arrangement in the motor relay circuit to provide these motor gas valves with complete phase failure protection. In accomplishing this it is necessary to utilize all available relay contacts and consequently it is impossible to have an external load control circuit through the relay.

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FATIGUE TESTING. Bulletin No. 5 describes various fatigue testing machines designed by H. F. Moore: Rotating Testing Machine, Flat Specimen Testing Machine, Repeated torsion Machine, Repeated Tension Machine, Reversed Bending Machine. J. B. Hayes Machine Co., Urbana, Ill.

DIFFRACTION X-RAY APPARATUS. Bulletin No. 10 covers the following apparatus: Clark-Hayes Cassette, Oscillating Spectrograph, Cylindrical Camera, Gas Type X-Ray Tube, Microphotometer and Goniometer Head. J. B. Hayes Machine Co., Urbana, Ill.

DIVIDING MACHINERY FOR THERMOMETERS, GLASSWARE AND METALS. Catalogue C-24 illustrates and describes thermometer graduators, and glass, paper, wood or ivory dividing machines. J. B. Hayes Machine Co., Urbana, Ill.

TUBE FURNACE, Bulletin 1014 illustrates the Model U Furnace for temperatures between 700 and 1400°C. This furnace is designed for combustion analysis and similar work. The Sentry Company, Taunton, Mass.

HUMIDITY RECORDER. A reprint from the Journal of the Optical Society of America and Review of Scientific Instruments, June 1926, pages 623 to 652. Leeds & Northrup Company 4901 Stenton Avenue, Philadelphia, Pa.

CHRONOGRAPHS. Catalogue B, 1930, 24 pages illustrates and describes: tape chronographs, drum chronographs, printing chronographs, recording drums and accessories, recording papers, regulator clocks and chronometers, stop watches and interval timers. Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago, Ill.

AIR OPERATED CONTROLLER. Catalogue 4000 illustrates and describes completely the operation and application of Bristol Air Operated Controller Equipment. 20 pages. Bristol Co., Waterbury, Conn.

INDUCTION REGULATORS. Leaflet L.20496 illustrates Type S Induction Regulators giving their application and distinctive features. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

THERMOMETERS. Leaflet describing the Foxboro Indicating Thermometers which are made in two sizes; 5 inch and 8 inch dial. All-metal construction. No glass tubes to break, or mercury to separate, easily read. It is a simple, practical, durable and permanently accurate actuating movement that gives absolute satisfaction to thermometer users. Foxboro Company, Foxboro, Mass.

FOG HORN is a pocket booklet which is put out by the Parks-Cramer Company. It contains articles on subjects of interest to the textile manufacturer. The October 1930 copy No. 61 contains the story entitled "The American System of Cotton Spinning. Parks-Cramer Company, Fitchburg, Mass.

ORIFICE METERS. 250 pages, fabrikoid book entitled "Principles and Practice of Flow Meter Engineering." This book discusses the application of the orifice meter for gas and liquid measurement. 1930, price $2.00. Foxboro, Company, Foxboro, Mass.

PANELBOARDS. 12 page booklet identified as Special Publication 1890. Contains typical panelboard specifications descriptions of Westinghouse panelboards, and many illustrations showing these panels and their construction. Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

REFRIGERATION CONTROLS. Loose leaf book on the Marsh Merkustat, and automatic control unit for mechanical refrigeration. Bulletin 5000, 20 pages. James P. Marsh & Co 2073 Southport Ave., Chicago, Ill.

MANOMETERS. 48 page pocket-size booklet entitled, "The Manometer and Its Uses." It is intended to fill the need for a handy and compact booklet dealing with the manometer, its operating principles and uses. Meriam Co., 1955 West 112th St., Cleveland, Ohio.

GEAR DATA AND FORMULAS. Catalogue No. 30, 96 pages gives complete information on the wide range of stock gears: spur, bevel, miter, spiral, etc. Ohio Gear Company, 1333 East 179th St., Cleveland, Ohio.

CONTROL PYROMETER. Catalogue No. 202, loose leaf, 38 pages contains the latest data on Republic Control Pyrometers, Valves and Valve Controllers. Republic Flow Meters Co., 2240 Diversey Parkway, Chicago, Ill.

RESISTANCE WIRE. 10 pages with tables, curves and descriptions of various electrical alloys, also a bulletin on Allegheny Ohmaloy. Gilby Wire Company, 150 Riverside Avenue, Newark, New Jersey.

PYROMETERS. A new catalog featuring Brown Indicating, Recording and Automatic Control Pyrometers. This catalogue contains 104 pages with 141 illustrations, many of which are in two colors. A resume of the theory and practice of applied pyrometry is presented, together with descriptions and illustrations of all instruments, thermocouples, protecting tubes and other required equipment. Brown Instrument Company, 4482 Wayne Ave., Philadelphia Pa.

DIVIDING MACHINES. Catalogue No. 508 of the Societe Genevoise d' Instruments de Physique of Geneva, Switzerland. It contains something of the history of the construction of linear and circular dividing machines. This new catalogue covers the re-design of all of their dividing machines in the last few years and represents the latest features incorporated in these linear and circular dividing machines. R. Y. Ferner Co., Investment Building, Washington, D. C.

MOTORS. Types AD and ADS Motors illustrated in leaflet L 20503 gives their application, distinctive features, operation, and construction. These motors are all given 21 distinct electrical tests during the process of manufacture. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

COMPENSATOR. Described in leaflet L 20505. Type RC Line-Drop Compensator, (rotary contactless) for use with induction feeder voltage regulators. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

TEMPERATURES. Bulletin Number 3, 1930 describes the old and new ways of controlling a heating plant, by the Duo-Stat System. It is the automatic heat regulation controlled by the outdoor temperature for all types of heating plants in all types of buildings with any kind of fuel. F. I. Raymond Company, 629 West Washington Blvd., Chicago, Ill.

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WAVEMETERS. August 1930 issue of the Experimenter, gives the accuracy considerations in the use of tuned-circuit wavemeters. The Experimenter is published monthly to furnish useful information about the radio and electrical laboratory apparatus manufactured by the General Radio Company, Cambridge A, Mass.

FURNACES. A Circular naming the plants that temper by the Homo Method and harden by the Hump Method. Also lists the plants using Homo nitriding furnaces. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

MICROMETERS. A booklet entitled "Precision Measuring Tools" describes and illustrates the various micrometers manufactured by the Swedish Gage Company, Detroit, Mich.

AUTOMATIC CONTROL. This booklet describes and illustrates how automatic control renders its aid as though it were humanly directing your process to meet changing operating conditions and requirements freeing the human element from its limitations. Brown Instrument Company, 4482 Wayne Ave., Philadelphia, Pa.

BEARING TESTER. This is a leaflet describing an acoustimeter for inspection of ball and roller bearings. The function, operation and advantages of the Burgess Bearing Tester are also given. Burgess-Parr Company, 111 West Monroe St., Chicago, Ill.

PYRATHERMS. Bulletin A-6 illustrates and describes a complete safety control with ignition cut-off, designed for flue installation. It provides positive protection against flame or ignition failure. The Mercoid Corporation, 4201 Belmont Ave., Chicago, Ill.

CONTROLLER. This circular describes the new Foxboro Dye-Tub Controller, which fits the modern trend in piece and batch dyeing. There are no cams, unnecessary levers or other needless nick-nacks to cause trouble in this new controller. It is of rugged simplicity and will give guaranteed accuracy throughout life. Foxboro Company, Foxboro, Mass.

SURVEYING INSTRUMENT. A circular entitled "Driftmeter Junior" giving the operation, maintenance and advantages is described therein. Driftmeter, Inc., 616 Exchange Bank Bldg., Tulsa, Okla.

INDICATORS. Bulletin 262. describes the Maihak Indicator which was built with the experience of over a half a century. The different sizes and kinds of Maihak Indicators are given and their particular uses. Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh, Pa.

POSITIVE DISPLACEMENT METERS. 200 page book entitled "Measurement by Displacement Meters." Price $1.00 each. Handbook E-4, 1930. American Meter Company, Inc. 105 West 40th St. New York, N. Y.

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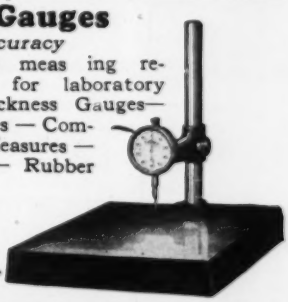

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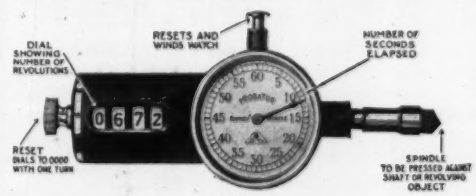
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M. F. BÉHAR,, INSTRUMENTS, Vol. 3, No. 11, pages 659-680, 23 figs.

Chapter IX—Industrial Humidity Instruments (concluded). This instalment covers: Recording Instruments—Two-Pen Recorders, Psychrometric Single-pen Instruments, Hygroscopic Recorders, Absolute Humidity Recorders. Automatic Control—Principles of Humidity Control, Classes of Applications, Relation of Humidity Control to Air Conditioning, Classes of Humidity Control Instruments, Humidity Apparatus.

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EDWARD T. POST, INSTRUMENTS, Vol. 3, No. 11, pages 681-684, 3 figs.

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MEASUREMENTS—INDUSTRIAL AND SCIENTIFIC.

DR. WALTER BLOCK, INSTRUMENTS, Vol. 3, No. 11, pages 685-693, 7 figs.

Chapter VIII. Measurement of Volumes (concluded). Water Meters and gas meters are discussed.

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E. OWER, INSTRUMENTS, Vol. 3, No. 11, pages 695-704, 7 figs.

Chapter VII. The Vane Anemometer. Several types are described.

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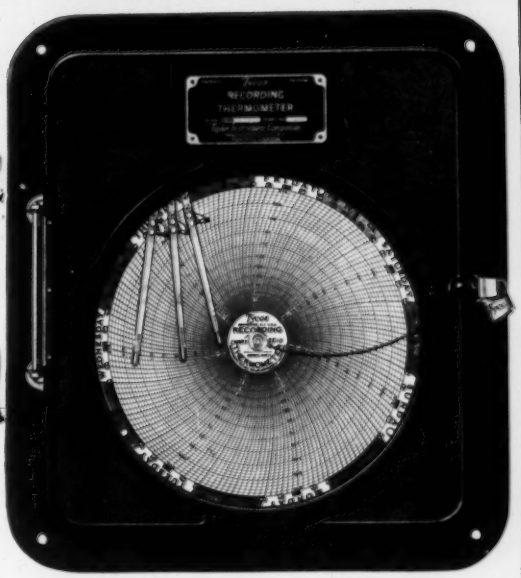

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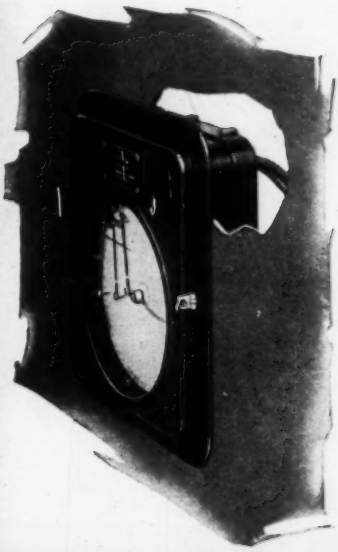

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